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VOLUME II.

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No. 1. — *The Art of the Farrier.*   By D. D. SLADE, M.D., Professor of Applied Zoölogy.

THERE is no portion of the animal frame that exhibits a more wonderful adaptation of means to the ends proposed, than the horse's foot; and it is only by careful observation and study that we can appreciate the wisdom therein displayed.

In a state of nature, the growth and wear of the hoof are maintained in perfect equilibrium. When, however, the animal is subjected to the service of man, this equilibrium is destroyed and the wear exceeds the growth; a condition which of course necessitates the protection of those parts which are exposed to this undue wear. This very protection, however, again destroys the balance between the growth and the wear, for the former soon exceeds the latter, requiring the removal of the protecting shoe and the reduction of the growth of horn either by natural wear, or by artificial means. This simple operation constituted the art of the farrier in the earliest ages; and such would it have continued, had not this simplicity been interfered with by numerous whims and superstitions which, gradually creeping in from generation to generation, have greatly obscured the original purpose of the art, and have converted a beneficial operation into one which, in many cases, is fraught with serious injury to the health and usefulness of the animal.

While much may be accomplished, by the publication of books and essays upon Farriery, to diffuse useful information upon this subject,

it is evident that, if it is desirable that a sure and steady progress should be made in all that pertains to the art, those who practise it must be instructed by others who have made the organization of the foot their study, and can base their teaching upon knowledge thus obtained.

Inasmuch as in the natural condition all parts of the foot come to the ground, the hoof of the young animal, which is brought to the forge for the first time, requires little or no preparation, beyond rendering the ground surface of the wall or crust perfectly level to receive the web of the shoe. The entire foot is in that condition best adapted for the artificial protection which, in his new relations to man, is hereafter to become a necessity to the animal.

The foot that has already been shod requires the removal not only of the shoe with its nails, but also of its ground surface, in order that it may be brought to a proper level. In the majority of cases, the growth of the wall downwards from the coronary cushion is greatest at the toe, which is to be accounted for by the firm attachment of the shoe at this point, not allowing the motion between the iron and the horn, and the consequent wear which takes place at the heels, where the attachment is much less. In levelling the wall, we must be guided by the following rules. The ground surface of the foot should be transverse to the direction of the pasterns, a condition which in most cases can be brought about by simply reducing the hoof at the toe to a level with the unpared sole. Too great obliquity of the foot, which is produced by the undue amount of horn at the toe, increases the general obliquity of the pastern, and this condition increases the strain thrown upon the flexor tendons or back sinews. This undue obliquity of the foot constitutes one of the chief evils which follows the too frequent custom among farmers and others of allowing the shoe to remain on the foot for an indefinite length of time without removal. This period should never exceed a month.

If, through neglect, the heels have been allowed to grow down beyond a natural limit, they must be lowered to an extent which will restore the ground surface to the desired level. Too great a height of heel renders the pasterns more upright, and consequently too great weight is thrown upon the pastern bones.

The operation so universally adopted by farriers of "opening up" the heels is one of the most barbarous, senseless, and useless proceed-

ings that could possibly be devised. It consists in making two deep incisions into the angles of the hoof at the heels, just as it turns inward to form the bars. The process destroys that portion of the foot which was expressly designed by nature as a buttress or defence against its contraction, and nothing could lead more surely to the destruction of the fulness and roundness which are distinguishing marks of a well-formed, normal foot. This important defence, then, should never, on any consideration, be mutilated.

The equally useless and unreasonable method of paring the sole, and of destroying the bars, of whose existence many are profoundly ignorant, should not be practised where the parts are in a healthy condition. By the removal of this portion of the foot, we expose the sensitive parts beneath to injury, by coming in contact with foreign bodies in travelling. If we examine carefully the structure of the sole, we shall find that its constant growth is removed by exfoliation, and that the parts beneath the external layer are not fitted to take the place of the latter until it has been removed by the natural wear. Paring out the sole of the healthy foot cannot be defended on any ground, neither can any artificial substitute be employed that can supply the place of the natural protection. In the event of casting a shoe while upon the road, no evil can befall the unmutilated sole; while that which has been subjected to the "paring out" process is liable to become seriously impaired, especially if this operation has been recently performed.

A better knowledge of the functions of the frog now prevents in a measure that destruction which was formerly so extensively practised upon this portion of the foot. There still exists, however, an innate desire on the part of many farriers to cut away not only the shreds, but also the substance, of this organ. This should never be done, as the parts beneath are immaturely called upon to assume functions for which they are not prepared; this process of exfoliation in the unshod hoof being the result of gradual wear. The frog, then, should be retained in its original integrity, if we would wish to prevent the diseases to which it is liable, and which are sure to follow its reduction by the knife.

Rasping the wall, before or after the application of the shoe, cannot be too strongly condemned. By this practice, the delicate external layer of horn which not only gives the beautiful polish to the

part, — a polish not to be imitated by any artificial means, — but which protects the layers of horn beneath, is removed, thereby rendering the crust more brittle and less well fitted for holding the nails. If the shoe is accurately fitted to the foot, and not the foot to the shoe, there will be no necessity for reducing the wall with the rasp at the toe, which gives a stubbed appearance, instead of the natural graceful outline.

" It should be ever most strenuously insisted upon, that the whole lower face of the hoof, except the border of the wall, must be left in a state of nature; the horn of the sole frog and bars has an important duty to fulfil; it is the natural protection to this part of the hoof; and no protection of iron, leather, or other material, is half so efficacious; in addition, it is a capital agent in sustaining weight, and in keeping the whole foot healthy and perfect in form." *

It will thus be seen to what a simple matter the preparation of the healthy foot for the shoe is reduced. To maintain this organ in a sound and perfectly healthy condition, we must guard especially against its mutilation.

The particular form of shoe to be applied is of far less importance than a strict adherence to the rules which we have laid down for the preparation of the foot. There are, however, several points to be considered. The shoe most frequently adopted presents a concave surface to the foot, and a flat surface to the ground; a construction evidently called forth by the mutilation to which the sole has been subjected, and which renders it totally unfit to sustain any pressure whatever. Exactly the opposite characteristics are exhibited by the shoe best adapted to the protection of the foot which has been preserved in its natural condition. It presents a concave surface to the ground, while the plain surface is attached to the foot. In this way, the wall and a portion of the sole are called upon to sustain a proportionate part of the weight, and there is much less chance afforded for the lodgement of stones and other foreign bodies between the web of the shoe and the foot. Whatever form be adopted, it is most essential that the shoe should fit the foot, and in its outline follow the exact shape of its ground surface. The usual method of shoeing, which allows considerable projection of the heels of the shoe, both in length and breadth, is in many cases objectionable, especially as no benefit

* Practical Horseshoeing, by G. Fleming, F.R.G.S., &c.

can be derived therefrom, and, when speed is required, there is always more or less danger of the shoe being torn off, by the other feet coming in contact with it.

The weight of the shoe must depend upon circumstances, but it should in all cases be made as light as the nature of the services of the animal will permit. Some curious statistics made by a French veterinary professor, show the importance of this consideration. He says, "If, at the termination of a day's work, we calculate the weight represented by the mass of iron in the heavy shoes a horse is condemned to carry at each step, we shall arrive at a formidable array of figures, and in this way be able to estimate the amount of force uselessly expended by the animal in raising the shoes that overload his feet. The calculation I have made possesses an eloquence that dispenses with very long commentaries. Suppose that the weight of a shoe is two pounds, it is not excessive, to admit that a horse trots at the rate of one step every second, or sixty steps a minute. In a minute, then, the limb of a horse whose foot carries two pounds, makes efforts sufficient to raise a weight of one hundred and twenty pounds. For the four limbs this weight in a minute is represented by $120 \times 4 = 480$ pounds; for the four feet during an hour the weight is 28,800 pounds; and for four hours, the mean duration of a day's work, in the French omnibusses, the total amount of weight raised has reached the enormous figure of 115,200 pounds. But the movement communicated to these 115,200 pounds represents an expenditure of the power employed by the motor without any useful result; and, as the motor is a living one, this expenditure of strength represents an exhaustion, or, if you like it better, a degree of fatigue proportioned to the effort necessary for its manifestation."

It is essential that the shoe should be of the same thickness throughout, for this insures a natural position to the foot and limb. Where calks are deemed necessary, they should be of equal height at toe and heel. The number of nails necessary to retain the shoe in its place is a matter of consideration, but hardly merits the controversies to which the subject has given rise from time to time. Regarding every nail-hole as an injury to the hoof, which it certainly is, it is at once evident that the number should not exceed that which is absolutely necessary. For the saddle or light-draught horse, not more than five or six in the fore, and seven in the hind, are required,

and these should be more widely distributed than is the usual custom. In driving the nails, it is of importance that the hold should be short, including within the group a comparatively small portion of the crust. The shoe is thus held more securely, and the injury to the horn is more speedily removed by the natural growth downward.

It would seem unprofitable to enter into the discussions which have arisen from time to time as to the propriety of applying the shoe and fitting it to the foot in a hot rather than in a cold condition. It must suffice here to say that experience has amply shown that the hot fitting will alone secure the proper and accurate application of the shoe, and that the slight scorching of the horn-fibres has rather the effect to preserve them against untoward influences, than to inflict injury.

Our remarks have been directed to the method of shoeing which is especially applicable to the healthy foot. Disease not unfrequently brings about changes which compel us to modify the system which we have advocated. Of these changes we do not propose here to speak.

The general management of the feet demands a few words. The right way of caring for the feet is the simplest possible, requiring nothing beyond strict attention to cleanliness. Washing the feet daily with clear water by means of a sponge, taking care afterwards to rub dry the parts above the hoof, and to avoid the use of any application in the form of oil or stimulant, &c., constitute all that is absolutely essential. The unmutilated sole forms in itself the best defence against the extremes of dryness or moisture; and the "stuffing" and other artificial measures so universally adopted are worse than useless, if the natural sole has been preserved. Neither can any thing be substituted for the beautiful polish which the unrasped wall presents in its healthy condition.

Placing the animal on a perfectly level floor, if he stands in a stall, or, still better, giving him the freedom of a loose box, will promote a sound condition of the feet and conduce to the general health.

No. 2. — *On the Amounts of Potash and of Phosphoric Acid in several Kinds of Rocks.* By F. H. STORER, Professor of Agricultural Chemistry.

FROM analyses published in the first volume of the Bussey Bulletin, page 161, note, it appeared that several kinds of rocks occurring in the immediate vicinity of Boston, contain so unusually small a proportion of potash that it became of interest to determine whether the fact was common to all the rocks of this locality, and whether, by any possibility, the generality of the rocks of New England were equally poor in respect to this constituent.

In order to test these questions, I have had a considerable number of rocks analyzed, with special reference to the amounts of potash and phosphoric acid which they contain. The rocks were from various localities, as will be seen from the table given below ; and the amounts of potash and phosphoric acid found in them were no less varied. This table, it should be said, includes the results previously given in Vol. I., p. 161.

GRANITES.

	Contained per cent of	
A Specimen of : —	Potash (K$_2$O)	Phosphoric Acid (P$_2$O$_5$)
Coarse feldspathic granite, from the South shore of Henshaw Pond, Leicester, Mass.	7.434	1.191
Rather fine-grained feldspathic granite, from "Oak Hill," on the border of Lowell, Mass.	5.803	0.060
Similar to the preceding, and from the same locality	5.904	0.058
Dark-colored, coarse granite, or syenite (?), from a quarry in Dracut, Mass., a mile and a half from upper Lowell bridge, on the road to Nashua	4.263	0.249
Coarse feldspathic granite, closely resembling the Leicester sample, obtained at a locality five or six miles distant therefrom in the adjacent town of Spencer	4.692	0.084
Very fine-grained granite from a quarry in Troy, N.H., at the base of Mt. Monadnock	3.659	0.112
Rather coarse granite, carrying a large proportion of mica, from ledge near new jail at Lowell, on line of Boston, Lowell, & Nashua Railroad	2.587	0.135

SYENITES?.

A specimen from quarry of Eastern Point Granite Company, Gloucester, Mass. The sample contained a large proportion of feldspar	5.304	0.066

Samples taken from two different quarries, close to Pigeon
    Cove, Cape Ann. · These samples were rich in feldspar
    and they were somewhat weathered 5.241   0.046
Chip taken from Boston Post-office building, said to come
    from quarries at west side of Gloucester, Mass. . . . 1.781   0.042
Chip taken from a stone-cutter's yard, said to have come
    from Quincy, Mass. 1.407   0.042

SLATES.

Dark micaceous schist from the granite quarry in Dracut,
    mentioned above 4.356   0.287
Finely ground and bolted slate, from Saco,* Maine, pre-
    pared and sold as a "fertilizer" by the Old Orchard
    Slate Co., of Portland, Maine . . . . . 4.180—4.373   0.089
Compact, blue clay-slate from "City Ledge,"* Somer-
    ville, Mass., half a mile or more west of the Milk Row
    quarry . . . . 3.875—3.913   0.085
Hard, close-grained, compact quartzose rock, seemingly an
    indurated sandstone passing into micaceous schist ; from
    Dracut bank of the river opposite head of Merrimack
    Street, in Lowell 2.956   0.145
Similar to the preceding, from ledge near Lowell gas
    works 2.468   0.296
Similar to the preceding, from bed of Merrimack River at
    Lowell, below the falls 1.635   0.136
Similar to preceding, from a ledge on bank of old canal,
    some 800 feet from the point where it leaves the Merri-
    mack River 1.433   0.148
Rhomboidal clay slate from quarry near old powder-
    house, Elm Street, Somerville, Mass. 1.294   0.098
Soft clay shale, from Morton Street, Jamaica Plain, near
    junction with Walnut Street 1.099   0.140
Compact dark-colored rock (? indurated sandstone) from
    Morton Street, as above 1.063   0.087
Soft clay shale from Everett, Mass., on borders of Chelsea,
    near corner of Chelsea Street and Everett Avenue . . 0.908   ——

SOAPSTONE.

From quarry of the Union stone Co., Groton, Mass. . . 0.370   0.162

TRAPS.
(Slightly decomposed in most instances, from exposure to the weather.)

Compact, light-gray, fine-grained, speckled rock from a
    dyke in ledge at Andrews Point, Pigeon Cove, Mass.

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   * The Saco slate contained 0.676% of lime (CaO) ; and the City Ledge
Slate, from Somerville, 1.316% of lime.

This rock appears to consist of a syenitic base through which crystals of orthoclase are scattered 5.568   0.037

Compact, fine-grained gray rock (? a somewhat altered diorite) from "red-gravel locality" on Clyde Street, Brookline, Mass. 0.997   0.121

Dark-colored, compact, fine-grained diorite (?) from Boston and Providence turnpike, West Dedham, Mass. . . 1.007   0.194

Similar to the preceding, from Chelsea Street, Everett, Mass., as above described 0.684   0.846

Dark fine-grained diorite, similar to the preceding, but carrying numberless minute specks of iron pyrites, from City Ledge, Somerville, Mass. 0.303   0.444

Rock, formerly called Syenite, from the Milk Row quarry (Dane's Ledge), Somerville, Mass., well known to mineralogists as a locality for phrenite and other minerals. From the analyses given below, it would seem as if this rock might fairly be classed as a diorite, though it differs very materially in texture and appearance from the diorites ordinarily found in the vicinity of Boston. The crystals of the minerals which compose the Milk Row Rock, unlike those of the common diorites of the region, are as large and coarse as those in the syenites ordinarily used for buildings ; and the rock itself, though massive, compact, and tolerably hard, as it exists in the solid ledge, disintegrates rapidly when exposed to the weather, and falls to a fine red gravel, that is much esteemed for spreading upon garden walks: —

I. A sample of the original undecomposed, or only slightly decomposed, dark-colored rock * from Dane's Ledge 1.464   0.539

* On further examination, it appeared that this particular specimen of the rock, dried at 110° C. contained per cent of: —

Silica.	Alumina and Ferric Oxide.	Lime.	Magnesia.
49.82	31.82	8.42	3.03

I find furthermore in one of my old note-books, for the winter of 1851–52, partial analyses of three samples of rock from the Milk Row quarry, to the following effect: —

	Loss on ignition.	Silica.	Alumina.	Ferrous oxide.	Lime.	Sulp. acid.
1st sample . . .	5.05%	46.18	15.62	23.93	6.51	0.45
2d „ . .	——	40.45	18.50	16.40	——	0.21
3d „ . .	5.69	38.58	19.46	——	.——	——

With regard to these figures it should be said that the "loss by ignition" does not truly represent the amount of water in the rock, since some of the ferrous oxide that is contained in it takes on oxygen during the ignition.

II. A sample of lighter colored rock from Dane's Ledge,
      which had manifestly begun to decay somewhat . . .   8.282   0.202

It has often been noticed by analysts,* that, as in the instance here
given, the proportion of potash in a partially decomposed rock may be
actually larger than it was in the original solid rock. The reason of this
apparent increase is found in the fact that the soda, or rather the silicate
of soda, with which the potash is associated in the rock, is often decom-
posed and washed away much more readily than the potash silicate.
Thus, Struve, as long ago as 1826, found among other things in a phono-
lite from Rothenberg: —

	Silica.	Alumina.	Lime.	Potash.	Soda.
In its natural condition . .	57.70%	22.80	1.05	3.45	9.70
In its weathered condition .	67.98	18.93	0.86	5.44	3.26

In a Basalt from Bohemia (Roth, p. 47) Struve found, —

	Potash.	Soda.
In the natural rock	1.35	7.85
In the weathered rock . . .	2.62	2.31

So, too, with rocks that, instead of having been exposed to the weather,
have been partially decomposed with an acid. Thus, for example: —

A phonolite from Wisterschan, analyzed by Redtenbacher, in 1839,
contained among other things, —

	Silica.	Alumina.	Lime.	Potash.	Soda.
In the natural condition . .	54.35%	23.98	0.68	4.26	9.16
In the part dissolved by acid .	41.22	29.24	1.03	3.56	12.11

A phonolite from Marienburg, analyzed by Meyer in 1839, contained,

	Silica.	Alumina.	Lime.	Potash.	Soda.
In the natural condition . .	54.46	19.98	2.22	9.17	2.67
In the part dissolved by acid .	43.24	21.00	2.99	0.04	7.11

The fact is analogous to, and is probably of the same order with, the
so-called fixing or absorptive power of soils; that is to say, the power of
aluminous silicates, such as occur in the soil, to fix and hold potash
rather than soda against solution and waste by leaching, as is explained
in Johnson's "How Crops Feed," New York, 1870, page 336 *et seq.*

SANDS AND QUARTZ ROCKS.

Quartz rock, with streaks of feldspar interspersed from
    Boston and Providence turnpike, West Dedham, Mass.   5.085   0.053
Quartz rock, from granite quarry in Dracut, Mass., about
    1½ miles from upper Lowell bridge on road to Nashua .   0.755   0.033
Another specimen from the last-named locality 0.271   0.028
Beach sand from Essex, Mass. A fine light-gray mica-
    ceous scouring sand, such as is sold by grocers for house-

There is doubtless some ferric oxide in the rock, though I did not determine
the amount. Special experiments are needed to determine what proportion of
the sulphuric acid found by analysis may have existed as sulphur, in the form
of pyrites, in the rock.

* Compare, for example, Roth's "Die Gesteins-Analysen," Berlin, 1861,
Article Phonolite, pages 22–24.

hold use. This sand consists of very fine and light particles, which have manifestly come to rest from the sea-water in some sheltered bay or cove.	2.384	0.051
Coarse dune sand of light reddish-brown color from a hill at Provincetown, Mass., collected by Capt. Nath. E. Atwood of that town	0.613	0.050
Pit sand from beneath field next adjoining the Plain-field of the Bussey Institution	0.891	0.035
Pure white Berkshire County sand obtained in 1872 from glass-houses in vicinity of Boston	0.448	——
Ditto, — Another sample obtained in 1874	0.630	0.021

The foregoing results consist perfectly with those observed in other countries, as may be seen by consulting the extensive collection of rock analyses published some years since by J. Roth, under the title "Die Gesteins-Analysen," Berlin, 1861. Stœckhardt also, in his "Chemische Ackersmann," 1862, S. 112, has drawn up a synopsis from which it appears that the amounts of potash contained in ordinary rocks are somewhat as follows: In pure potash feldspar, there is found from 10 to 16% of potash; in potassic mica and in several kinds of volcanic rocks 8 to 10%; in certain Saxon feldspars and green sands, phonolite from Bohemia, pumice and trachyte from the Rhine 7 to 8%; in granulite and porphyry from Saxony and Austria, in some mica slates, roofing slates, and phonolites 6 to 7%. In some kinds of granites, syenites, gneisses, and mica slates 5 to 6%; in other kinds of the rocks last named, and in some clay slates, porphyries, and traps 4 to 5%; in still other kinds of the rocks just named, 3 to 4%; in certain Swiss granites, in gneiss from Sweden, in mica slate and clay slate from Saxony, and in various volcanic rocks 2 to 3%; in various clay slates and basalts 1 to 2%. Hornblende slate, serpentine, &c., are often still poorer than this in potash and so are many lime stones.

Boricky, in his treatise "Ueber die Verbreitung des Kali und Phosphorsäure in den Gesteinen Böhmen's," Prag, 1872, gives the maximum and minimum amounts of potash that have been found in granites as 2 and 7%; in gneisses the amount of potash ranges from 2 to 5%, in granulites and syenites from 1 to 7%, in porphyritic rocks from 1.3 to 7.9%, in mica slates from 1 to 4%, in clay slates from 1 to 6%, and in basalts from 0.5 to 4%. He found that *phosphoric acid* ranged from 0.1 to 0.5% or more, in the fine grained granites, and that there was rather more (about 0.5%) in gneissoid

granites, and in certain mica slates. In the slates, however, the proportion of phosphoric acid naturally varied, accordingly as the stones were or were not fossiliferous; but little of the acid was usually found in slates from old formations destitute of fossil remains. Appreciable quantities of phosphoric acid were found in most basalts; and the amount was not infrequently decidedly high, often as high as 1%. Boricky (page 38) sums up the results of his search for phosphoric acid in the Bohemian rocks in the following terms : " There are few rocks which can be proved to be totally devoid of phosphoric acid. Traces of the acid, at the least, may be found in nearly every rock and in almost every soil; but there are few rocks in which the proportion of phosphoric acid exceeds one per cent."

Nessler,* who has recently had a large number of German rocks examined with regard to potash and phosphoric acid usually found in dolerite from 0.6 to 2.% of potash and about 0.5 to 0.8% of phosphoric acid. The minimum amount of potash observed by him in a diorite was 0.3% and of phosphoric acid 0.03%; the maximum amount of potash in a dolerite was 4.3% and of phosphoric acid 1.1%. In trachytes he found 3 or 4% of potash, and from 0.4 to 0.66% of phosphoric acid.

It is always of interest to the farmer to know what connection, if any, there may be between the soils of his fields and the rocks with which he is familiar, and in many countries it is comparatively easy to study the relations which the rocks bear to the soils. But the fact that the surface of New England is almost everywhere covered with the so-called drift-formation, that is to say, with gravels, sands, and clays that have been brought, as such, to their present positions from some other place, usually from some more northern locality, makes it difficult to trace the soil of any given farm or field in this region to the rocks from whose decomposition it was originally derived, or to determine what influence, whether for good or evil, the rocks of a locality may exert upon its fertility. It is well known that soils which have been formed in place, as the term is, that is to say from the decomposition of rocks which repose immediately beneath or beside them, are exceptional in this part of the country. They are comparatively rarely found covering any considerable area.† But it is, nevertheless,

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* Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1870–72, 13–15. 18.
† Compare Johnson's "How Crops Feed," New York, 1870, page 148.

true that the beneficial influence of rocks rich in potash, like several of the granites mentioned above, may sometimes be plainly seen in the luxuriant vegetation upon patches of soil at the bases of ledges of such rocks, or in hollows among the rocks upon which the products of their disintegration have fallen, or whither they have been washed by rains. In the vicinity of Gloucester, at Cape Ann, I have myself noticed not a few cultivated fields and many small patches of pasture grass whose luxuriance was clearly to be ascribed to supplies of food afforded by the crumbling granite of the immediate vicinity.*

The good effects produced by such rocks must manifestly often be hastened and increased by the method of cultivation, so common among us, in which brush-burning finds place, since the surfaces of the rocks are much broken and crumbled by the action of fire.

It would be interesting to observe in many localities, what rocks seem to nourish the neighboring vegetation through the products of their decay, and to note whether the soils that result from the decay of such rocks derive any peculiar benefit from the application of spe-

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* Since the above was written, I notice that attention has already been called to these appearances in the neighboring locality of Marblehead, by Mr. J. J. H. Gregory of that town, in a striking paragraph which I copy from the "Transactions of the Massachusetts Society for Promoting Agriculture," New Series, vol. i. pt. 3, p. 351.

"Formed for the most part from the decomposition of her primitive rocks, the soil of Marblehead, though scanty, is proverbially strong, covering our pasture lands, that have been closely fed over a century and a quarter without any cultivation or manuring, with a carpet of white clover during the rainy season. The soil of our islands is so amazingly productive of the grasses as to set all the attempts of the chemist to explain the fact from the chemical composition of the soil at defiance; no one can realize it until he has visited them during the growing season (Baker's Island is an instance), and I challenge any one to explain it by any theory that does not ascribe an influence far greater than has heretofore been customary to the qualities communicated to the air from the surrounding ocean."

With regard to the last part of Mr. Gregory's statement, it should be said that the explanation of the influence of sea-air upon the fertility of granitic soils is really not far to seek. The matter is readily explained, in good part, if not entirely, by a reference to the familiar facts that fields near the sea are kept moist well-nigh continuously by fogs and mists as well as rains, during the growing season; that the air near the sea is, comparatively speaking, highly charged with particles of salt, and that salt when absorbed by the soil has the power of liberating potash from some of its combinations in such manner that plants can freely feed upon it, as was discovered in 1850 by Professor Way, and as has been clearly described by Professor Johnson, in his "How Crops Grow," New York, 1870, p. 336.

cial manures. As has been stated already on page 269 of the first volume of this Bulletin, the fertilizing effects produced by spent bone-blacks upon the soils of south-western France indicate as clearly as the analyses of the rocks of the region that potash must there be natu-rally abundant in the soil. It is a question whether the good effects obtained by the use of nitrogenized superphosphates in many special localities in this country might not be explained in like manner by the intelligent observation of the rocks of these localities and of the influence which the products of their disintegration exert upon vege-tation.

The fertilizing influence of the wash of roads in some localities and of street-sweepings has been often remarked, and the traditions concerning them are sufficiently familiar to most practical men. But, as Stœckhardt * long since pointed out, what little value these sub-stances may really possess must largely depend upon the composition of the stones or gravel of which the road has been built. The fertil-izing action of the wash or the sweepings is doubtless due, in most instances, to phosphoric acid or potash or lime, naturally contained in the materials of which the roads are made, and set free therefrom or made available for the support of plants through pulverization, rather than to the comparatively small amount of the dung of animals dropped upon the road or to any mere moistening effect produced by the water that flows from the road.

This illustration has value as tending to show how little worth the cost it would ordinarily be to pulverize rocks artificially, in order to apply their powders as manure; for the wash of roads, and street sweepings, though often useful and sometimes valuable fertilizers, can in no wise be classed as strong manures, all possible allowance being made for the dung in them, and for the water of the wash, as well as for their powdery condition. If expressed in terms of money, their value would be seen to be exceedingly small, excepting perhaps some unusual and quite extraordinary instances.

The analyses of the sands above given were made in connection with experiments upon the growth of plants in these sands. Some of the results of the culture experiments have been described already in Volume I. pp. 56–63, and the others will be published hereafter. For the present it need only be mentioned that the indications afforded

* In his " Chemische Feldpredigten," Leipzig, 1856, 2. 108.

by analysis with regard to the comparative fertility, or rather sterility, of these sands generally agree very closely with those which have been obtained by the method of cultivating plants in the sands. Indeed I am inclined to believe that the fact is a general one, and that it will probably be found to be true, or very nearly true, of most sands and of soils that are equally sterile with the sands, excepting always clays and exceedingly fine rock-dust, which cannot easily be tested by the method of plant culture, since the fine adhesive particles of clay, or the like, clog the root-pores and present very serious mechanical obstacles to the growth of plants. In other words, contrary to what is now commonly believed to be true of most cultivable soils, it appears that the chemical analysis of exceedingly poor soils, devoid of organic matter, is competent to detect their peculiarities and to afford a tolerably correct idea of the comparative capabilities of such soils to support plants.

At first sight it may seem somewhat surprising that the sands should contain such comparatively large proportions as they do of potash and phosphoric acid. But the fact that sands are seldom free from these constituents has long been known and has been often insisted upon. Those chemists in particular who have occupied themselves with experiments by way of sand-culture have frequently lamented the practical impossibility of obtaining sand absolutely free from matters such as potash, phosphoric acid, and the other essential elements of the food of plants. Wiegmann and Polstorff [*] in their experiments of 1842, dwell upon this difficulty, and Hellriegel,[†] the most successful of all the experimenters upon sand-culture, was forced to content himself with sand that was not absolutely free from such contamination.

Professor Senft, has well said [‡]: "In ordinary life we often conceive of sand as if it were an aggregation consisting of nothing but grains of quartz. But the idea is a false one; and, because of its falsity, it has given rise to many erroneous conclusions, both as to the comparative fertility of the so-called sand-soils; with regard to what is required by different kinds of plants from the soils that support them; and, in general, as to what constitutes the necessary food of plants." . .

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[*] "Flora," 1843, **26.** 27.

[†] Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1861–2, **4.** pp. 112, 113.

[‡] In his "Steinschutt und Erdboden," Berlin, 1867, page 195.

"Almost every kind of sand must be regarded as a mixture of mineral fragments of different kinds." Senft holds * that dune sands usually contain from 2 to 25% of mineral fragments other than quartz. On carefully examining several samples of diluvial sands, he obtained results as follows: In a sand from the Mark Brandenburg he found grains of hornblende to the extent of 2%, and grains of orthoclase (potash feldspar), to the amount of 17%.† In a sand from Lusatia he found 25% of orthoclase and some mica also. A sand from the Lunenberg heath gave him 4% of basalt grains, and one from Mecklenburg yielded 10% of orthoclase and 2% of basalt. The fact, long held to be anomalous, that oaks are found in excellent growth on sand (if moist) in the Mark Brandenburg, was satisfactorily explained by Senft's analysis of that sand, as given above.†

Alexander Müller ‡ found, like Senft, wide variations in the proportion of quartz contained in sands. Müller's results are specially important, moreover, since they were not obtained by any process of mere inspection, or of mechanical separation, of the several kinds of particles, but by a refined and trustworthy method of chemical analysis of his invention, which enables the experimenter to separate every thing from the quartz, and to arrive at a very close approximation to the true amount of the latter. In a sea-sand, such as an ordinary observer might have taken for almost pure quartz, and which did actually contain a larger proportion (77%) of quartz than any other of the samples which he examined, Müller found that nearly a quarter part of the sand consisted of other minerals, of which feldspar was the chief. Another very fine-grained sand contained less than 70% of quartz, and a sample of Silurian sandstone contained less than 63%. Fine earth sifted (through meshes of ⅓ millimetre diameter), from land composed of glacial deposits, contained only 40% of quartz, and so did a sample of diluvial sand. According to Müller, the amount last named is but little larger than what is found in many granites.

It is noteworthy that, naturally enough, the question of the chemical composition of sands has attracted much more attention from foresters who have had to do with the planting of waste tracts than from

* Op. cit., p. 200.

† According to Nisbit, "Transactions of the Highland and Agricultural Society of Scotland," 4th Series, 1876, 8. pp. 288, 290.

‡ "Die landwirthschaftlichen Versuchs-Stationen," 1868, 10. pp. 157, 158.

farmers. Wessely * in particular has not only himself made a number of analyses of sands, but has compiled a considerable amount of information relating to this special subject. The following particulars are extracted from his treatise which relates to the planting of sand dunes.

ALLUVIAL DRIFT-SANDS.

Maxima and minima obtained in several analyses: —

	(K_2O) Potash.	(P_2O_5) Phosphoric Acid.	(CaO) Lime.
From sea-coast dunes in North Western Germany	0.73–0.89	trace	0.14
From inland dunes in North Western Germany (ordinary sand)	0.65–1.99	trace	trace to 0.03
From inland dunes in North Western Germany (loamy sand)	1.31	trace	0.04
From Hungary, dunes near Pesth.	0.86	——	——
From Hungary, dunes in the Banat.	1.06–1.45	trace to 0.08	5.31–9.06

Of the samples of sand examined in the Bussey laboratory, it may be said that the scouring sand from Essex contained so much visible, undecomposed mica, that the presence of potash was fairly to be inferred even from the most superficial observation. The pit-sand contained many grains that were evidently not pure silica, as was explained on page 56, Vol. I. The coarse dune-sand from Provincetown, though it contained a much larger proportion of quartz grains than the pit-sand, was by no means free from particles of other minerals. The Berkshire sand on the contrary is a sand of exceptional homogeneity and of exceedingly attractive appearance. It seems to consist entirely of minute, angular, glistening, white fragments of pure quartz ; though, from the very whiteness and brilliancy of the mass, it would be difficult to distinguish by mere inspection one particle of it from another. I have not yet found time to analyze a sample of this sand mechanically by way of elutriation, or to verify my suspicion that it may perhaps contain a certain percentage of minute flakes of mica or kaolinite. The Berkshire sand, as obtained by me for experiments upon the growth of plants, has been washed with water in order to remove any specks of dirt that might injure its appearance in the eyes of the flint-glass makers by whom it is chiefly used, and has been thereafter dried in kilns.

* "Der europäische Flugsand und seine Kultur," Vienna, 1873, pp. 43, 303, 305, 312.

SHALES OF THE CHEMUNG GROUP, FROM OWEGO, TIOGA COUNTY, NEW YORK.

While occupied with the investigation of some of the Massachusetts rocks above enumerated, in the autumn of 1875, I received a communication from George Sidney Camp, Esq., of Owego, N.Y., expressing a suspicion that certain shales of the Chemung group of rocks, underlying the soil in that vicinity, must contain a noteworthy amount either of phosphoric acid or of potash. In response to my suggestion that I would be glad to have the rocks analyzed, Mr. Camp sent me a number of specimens of the shale and of fossils by which to identify its geologic position. It is plain, from the characters of these fossils, that most, if not all of the shales belong to the Chemung group of rocks, as Mr. Camp was himself well aware. The localities of the specimens analyzed are described by Mr. Camp in the following terms : —

"I send you several specimens of what I suppose to be really the same thing.

"A hill 500 or 600 feet high, stands immediately north of this village (Tioga), crowned by a public cemetery, and it is commonly designated as the 'Cemetery Hill.' McMasters Street and North Avenue unite at its western base, and from this base on a level with the street and almost immediately opposite the junction of these streets, I took specimen No. 3, marked 'W. end.' From the southern face of the mountain, at an elevation of about 300 feet above the first locality, and 100 or 200 rods easterly from it, I took Nos. 2 and 2*. No. 4 is a specimen of a great deal of the soil of which the mountain is composed ; i.e., simply the disintegration of these rocks. Nos. 2 and 2 * were taken from Parker's quarry. The rocks from the same ledge, the courses of which consist more largely of sand, are taken for the cellars in this village. No. 1 is from Baker's quarry, at the same elevation as No. 2, but 50 rods further east, and apparently a continuation and outcropping of the same ledge. I took the specimens from the ledges and not from the debris. The more sandy layers contain very large quantities of fossils and some bits of fossil wood, of which the grain and characteristic marks are all obliterated. I send you one specimen,† however, which is not at all like those I have just referred to, but is found in, or in the immediate vicinity of, the Parker quarry. In a depression of the same mountain where it is worn by a stream to the level of the ledge from which specimen No. 3 was taken, but about three quarters of a mile further north, was taken another specimen of fossil wood, which has been figured in the Natural History Survey of the State."

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† The fossil here in question seemed to Professor Shaler to belong to the so-called millstone grit rather than to the Chemung group, and he suggests that some patches of the grit may perhaps crop out in the locality.

The specimens, excepting the soil and fossil, were all of green or olive-colored soft slates or shales, such as would readily disintegrate and fall to coarse powder under favorable conditions. On analysis it appeared that there was contained in

No. of the Specimen.	Potash (K_2O).	Lime (CaO)	Phos. Acid (P_2O_5).
1 (from Baker's Quarry)	2.935	0.325	0.129
2 (,, Parker's ,,)	5.181	0.400	0.203
2* (,, ,, ,,)	5.560	0.029	0.148
3 (,, W. end)	3.583	0.457	0.147
4 soil from disintegrated rock	3.068	0.320	0.165

Since these shales are soft and friable, and easily decomposed on exposure to the weather, and since they occur in close connection with "drift" soils that have been formed by the decomposition of rocks of another character, it is not improbable that the discovery that the shales contain so considerable a proportion of potash, may have an important influence upon the agricultural practices of the region in which they are found.*

Mr. Camp informs me that the disintegrated shale crumbles from portions of almost every ledge of rocks in that section of the country, and that the soil of the tops of the hills, and that of most of their slopes is chiefly or wholly composed of it. The shale itself crops out on nearly every farm in the extensive region underlaid by the Chemung group of rocks. At every quarry, rubbish from the shale collects in large quantities, and the proprietors are put to great inconvenience in the effort to get rid of it. I learn from Mr. Camp that there are in his vicinity — besides swamp lands underlaid with impermeable clays, and bottom-lands on the creeks and rivers which have no very distinct character of their own — two distinct classes of soils; viz., first, and most extensive, the flat or angular gravelly soil of the hill tops and many slopes, which consists of the disintegrated shale, and, second, the drift soil underlaid and filled with fragments of rounded pebbles

* Instances of the use of crumbly shales as fertilizers are not wanting in the history of agriculture. According to Sander, through lack of meadows in the wine region of the Moselle, no more dung could be procured there than was sufficient to give the vineyards a dressing of that material once in every five or six years. But during the intervening years the ground was strewn with finely broken bits of slate, which disintegrated in a single year. (Beckmann's "Beyträge zur Oekonomie," u. s. w., 1781, 5. 300). So, too, Fraas in his "Geschichte der Landbau und Forstwissenschaft," 1865, p. 282, mentions the use of lias shale for manuring hops in Franconia.

mostly from regions lying to the north. This drift skirts the feet of many hills, and forms extensive rounded knolls, or, often, hills of considerable elevation. Mixtures of the drift and sedentary soils naturally occur also.

It is not a wheat region, but the soil is esteemed to be peculiarly well adapted for maize and potatoes. Very large crops of potatoes were formerly grown there. Forty or fifty years ago four hundred bushels of potatoes to the acre were sometimes harvested, but nowadays one hundred and sixty or two hundred bushels are considered good crops. Fifty or sixty bushels of corn to the acre is not an infrequent yield at the present time, and rarely as much as one hundred bushels of shelled corn to the acre are still obtained. Formerly one hundred bushels of corn to the acre was not an infrequent yield.

Gypsum has been much used with good effect on the high and dry land, but not on the low-lying river or creek bottoms. Mr. Camp has himself obtained excellent results with wheat, and grass seeded down with the wheat, by applying lime to the shaly soil; and one of his friends recently harvested two hundred bushels of ears of corn, to the acre, from land that had been dressed with ammoniated superphosphate of lime, at the rate of about two hundred pounds to the acre.

The small proportion of lime in the shales of the Chemung group was insisted upon long ago by Emmons,[*] in one of the Reports of the Survey of the Natural History of the State of New York. The fact is not peculiar, however, to these New York rocks. A number of analyses of Devonian Slates from various localities equally poor, or even poorer, in lime, are given in Roth's "Gesteins-Analysen," and Daubeny [†] found the same thing to be true of several Welsh slates examined by him. Daubeny suggests, in this connection, that it is as true of lime as of phosphoric acid, that its absence from a rock would seem to indicate the want, and its deficiency the paucity at least, of lime-secreting beings. But it is possible of course that calcareous shells, or the like, may have once been commingled with the mud or ooze at the bottom of the sea from which the shales were formed, and have been afterwards removed by chemical means; that is to say, by the solvent action of sea-water or of carbonic acid.

It will be noticed that the proportions of phosphoric acid observed

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[*] Emmons, E., Agriculture of New York, Albany, 1846, 1. 198.

[†] "Journal London Chemical Society," 1855, 7. 296.

in the Chemung shales accord very well with the facts that the material from which the shales were formed was deposited in deep water, and that the fossils found in the shales are not the remains of animals such as have bones. Only the casts of sea-shells are to be seen in my samples.

Two of the samples of rocks from Mr. Camp were re-examined, for the purpose of obtaining an idea of their general composition. The results of these analyses were as follows : —

No. of the Specimen.	Silica.	Alumina and Ferric Oxide.	Lime.	Magnesia.
1 (from Baker's quarry) . .	69.63%	22.61	0.3859	1.42
3 (from W. end)	66.46	24.20	0.4785	1.45

ANALYSES OF MUDS FROM DEEP-SEA BOTTOMS.

With the view of testing the question, whether mud obtained from the bottoms of deep seas may not sometimes be equally poor in lime with the slates above described, I have examined a number of deep-sea deposits and have had quantitative analyses made of several such deposits as will appear from the following list.

Most of the samples of deep-sea soundings accessible to me, obtained by officers of the U. S. Coast Survey, off the coast of Florida and from the course of the Gulf Stream or its vicinity, effervesced strongly with acids, and were manifestly so highly calcareous, that no information bearing upon the question in hand could have been obtained from their analysis.

The samples actually investigated were obtained by Lieutenants Brooke and Berryman of the United States Navy, by means of the deep-sea sounding-apparatus invented by Lieutenant Brooke. The samples belonged to the Museum of Comparative Zoölogy at Cambridge, and were most kindly placed at my disposal by Mr. L. F. de Pourtalès, Keeper of the Museum.

In the following list, the numbers of the specimens are those which were marked upon them as they came to me from the Museum. The depths and places from which the specimens were taken are given in the note at the foot of page 22. It is to be observed that the analyses, though made with the utmost care, are in one sense partial; since no effort was made to estimate the amounts of carbonic acid, sulphuric acid, or other ingredients that may have been contained in them. In the cases where no determination of potash is recorded,

the amount of material at my disposal was insufficient for the estimation of this substance.

The results of the analyses were as follows: —

	No. 17.*	No. 12.	No. 8.	No. 4.	No. 6.	No. 1.	No. 3.
Silica (and sand) .	. 51.10	49.52	65.61	68.63	60.60	70.66	74.82
Alumina (manganese) and ferric oxide . .	. 7.75	8.82	14.91	14.40	19.01	16.58	12.41
Lime	. 18.76	17.08	1.39	1.68	2.74	1.71	2.52
Magnesia	. 1.73	1.77	3.29	2.58	1.59	2.58	2.05
Phosphoric acid . .	. 0.32	0.19	1.96	0.66	1.86	0.31	0.33
Potash	. 5.29	2.12	——	2.13	——	4.06	2.68

Samples Nos. 12 and 17, obtained broad off the coast of Nova Scotia at or near the northern edge of the Gulf Stream, are rich in lime, and are akin in this respect to specimens from the more southern portions of the Atlantic coast. The other samples analyzed contain comparatively little lime. They were obtained by Lieutenant Brooke in the Pacific Ocean between California and China, in the track of the equatorial and North Pacific currents. No. 8, brought up from a depth of 2400 fathoms broad off the coast of California, contained 1.39% of lime; No. 4, from 2500 fathoms in mid-ocean east of the Sandwich Islands, contained 1.68% of lime; No. 6, from 2600 fathoms, nearer the Islands, contained nearly twice as much lime, viz., 2.74%; No. 1, from 3000 fathoms between the Phillipine and Ladrone Islands, contained 1.71% of lime; and No. 3, from 900 fathoms in the China Sea, southwest of the island of Formosa, contained 2.52% of lime.

The proportion of lime in the Pacific muds, though small, is still much larger than that found in the Chemung shales, which, as was

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* The samples came to me marked as follows : —

No. 17. Berryman, 1857. Depth, 1298 fathoms. Lat. 42° 57' 40." Long. 60° 04.'

No. 12. Berryman, 1857. Depth, 1076 fathoms. Lat. 42° 55' 18." Long. 63° 26' 35".

No. 8. Brooke, Oct. 3, 1858. Depth, 2400 fathoms. Lat. 31° 06' N. Long. 129° 49' W.

No. 4. Brooke, Oct. 30, 1858. Depth, 2500 fathoms. Lat. 21° N. Long. 144° 25' W.

No. 6. Brooke, Nov. 4. 1858. Depth, 2600 fathoms. Lat. 20° 52' N. Long. 151° 51' W.

No. 1. Brooke, May 10, 1859. Depth, 3000 fathoms. Lat. 18° 08' N. Long. 129° 33' E.

No. 3. Brooke, May 16, 1859. Depth, 900 fathoms. Lat. 21° 52' N. Long. 119° 24' E.

suggested above, have probably been deprived of lime by chemical action.   It is of interest to note that the proportion of magnesia in the samples analyzed is commonly unusually large where the amount of lime is small, as it naturally would be in case a mud containing calcareous casts or shells had been exposed to the solvent action of weak chemical agents, such as would dissolve carbonate of lime rather than carbonate of magnesia.

The Pacific muds were all highly siliceous, as will be seen from the table of analyses.   No perceptible bubbles of carbonic acid were given off from either of them on the addition of muriatic acid. Most of them contained small quantities of manganese.   The variations in the amounts of potash and phosphoric acid found in the different samples of muds are noteworthy.

I have to thank my assistant, Mr. J. Andrew Henshaw, for much of the analytical work upon the rocks and muds above enumerated, and to testify to the great care and assiduity with which he has conducted the work.

The methods of analyses employed in most instances for the rocks were as follows: —

Potash was estimated by the method of Professor J. Lawrence Smith, familiar to American analysts.

To estimate phosphoric acid, eight grammes,* or thereabouts, of the finely powdered rock were heated in a platinum crucible together with four or five times as much carbonate of soda, that had been proved to be absolutely free from any contamination of phosphate, until the entire mass was in a state of calm liquid fusion.

The fusion was commonly effected without difficulty by means of powerful gas-burners or with an alcoholic blast-lamp (eolipile).   A few of the specimens were so refractory as to resist in some degree the fusion by means of lamps, but these exceptional rocks were quickly reduced by the following method, which I would commend to analysts as a neat and effective process: The platinum crucible which contains the rock and flux is fitted to a triangle of iron wire guarded with bits of pipe-stem. By bending the long wires which form its three points, this triangle is hung from the rim of a small Hessian crucible, from which the bottom has been knocked off, in such wise that the loaded platinum crucible may rest on the triangle within and at the centre of the Hessian crucible without touching the latter at any point.   The small Hessian cruci-

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* In some instances, where the amount of phosphoric acid was supposed to be small, quantities of the rock very much larger than eight grammes were fused as above described; but there was no advantage in using these larger quantities, and the fusing of them was inconvenient and troublesome.

ble with its contents is placed in a larger Hessian crucible, a cover is put upon the latter, and the whole is placed in the anthracite fire of a stove or furnace, such as are used for warming houses in this part of the country. In this way, the platinum crucible may be exposed to very intense radiant heat without the least risk of any foreign matter getting into it or of its being injured either by the fire or by the earthen crucibles. Care must be taken, of course, that the crucibles are not heated too quickly, lest the pasty mass of rock and carbonate should boil over through the sudden evolution of carbonic acid.

Fusion having been accomplished, the mass was treated with dilute nitric acid. It was found in every instance that the rock had been completely decomposed. The nitric acid solution was evaporated upon a water bath, and the residue was heated upon the bath (but at no higher temperature) for a long time, in order to render the silica insoluble, the heating being persisted in until no trace of acid fumes could be detected.

In many instances, the silica had to be heated several days upon the water bath, in order to free it completely from the adhering acid. The thoroughly dried silica, etc., was moistened with nitric acid, the mass was treated with water, the silica * was collected upon a filter and thoroughly washed, the filtrate and wash waters were evaporated to the volume of about 100 cc., a solution of molybdate of ammonia, prepared according to Fresenius, was added to it, and the acid mixture was kept at a temperature of about 75° during six or eight hours, or until the phosphoric acid had been completely precipitated. The yellow precipitate was dissolved in warm dilute ammonia, and filtered in the usual way, the filtrate was nearly neutralized with chlorhydric acid, and a very small excess of magnesia mixture as recommended by Fresenius† was added, together with as much strong ammonia as was equal to one-third the volume of the liquid, which did not exceed 100 or 110 cc. all told. The mixture, after standing over night, was filtered, and the precipitate was collected, washed, ignited, and weighed with the precautions enjoined by Fresenius.

Lime was determined in the usual way ; viz., by fusing the powdered rock with an excess of carbonate of soda, treating the fused mass with

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* In order to test the question, how much, if any, phosphoric acid was retained by these bulky silica precipitates, an experiment was made as follows: The thoroughly washed, still moist silica, equal to about 27 cc. in bulk, that had resulted from the decomposition of rather more than ten grammes of a syenite rich in quartz, was percolated, little by little, with 100 cc. of strong ammonia water, then washed with water, and the percolate and washings were evaporated to dryness at 100°, with the addition of a small quantity of nitric acid. The residue was moistened with nitric acid, was treated with hot water and filtered. The filtrate, on being digested with molybdate of ammonia at 80° during six or seven hours, gave a very slight yellow precipitate, which, when dissolved in ammonia and treated with magnesia mixture, gave a mere trace of precipitate, altogether too small to admit of estimation.

† "Anleitung zur Quantitaven chem. Analyse," 1878, p. 408.

dilute chlorhydric acid, separating iron and alumina by means of ammonia and precipitating lime in the filtrate as an oxalate.

For the analyses of the deep-sea muds, the samples were dried at 100° C.; the solution in strong hot chlorhydric acid was evaporated to dryness upon a water bath to separate silica; iron and alumina (together with manganese when present) were thrown down by means of ammonia; and the lime by means of oxalate of ammonia in the usual way.

In case the appearance of the carbonate of lime or the caustic lime obtained on ignition was unsatisfactory, the product was redissolved in dilute acid, the solution was filtered, and the lime was reprecipitated from it. The filtrate from the lime was divided into two portions, in one of which magnesia was determined as pyrophosphate; and in the other potash, as chloroplatinate. Phosphoric acid was determined by fusing the iron and alumina precipitate with carbonate of soda, and treating the nitric-acid solution of the fused mass with molybdate of ammonia, as described above.

I am indebted to my friend, Professor N. S. Shaler, for advice and counsel concerning the names of rocks; and to Messrs. F. P. Pearson, of Lowell, J. A. Beatley, and F. W. Very, for collecting many of the specimens. Several of the analyses were performed by Messrs. Beatley and Very, formerly my assistants, but most of them by Mr. Henshaw, as has been stated above.

No. 3. — *On the Agricultural Value of Spent Dye-woods and Tan.* By F. H. STORER, Professor of Agricultural Chemistry.

THE questions, how much, and what kind of value, as manure, have spent tan and dyewoods? are still often asked, although a great deal of information that might serve for answering them has long since been published. I have endeavored to collect some of this scattered information and to re-enforce it by new analyses of several spent materials, such as are accessible to many farmers in New England.

The character of the substances examined under my direction will appear from the following statements.

TANS AND SPENT TANS.

I. Fresh, ground hemlock* bark from Moseley's tannery, Winchester, Mass.

II. Spent tan from Moseley's tannery, as above.

III. Fresh, ground hemlock bark from the tannery of Waldmyer & Co., Winchester, Mass.

IV. Spent tan, from Waldmyer & Co.

V. Fresh, ground hemlock bark from the tannery of Blake, Higby, & Co., Woburn, Mass.

VI. Spent tan, from the tannery of Shaw and Taylor, Woburn,

All these specimens were obtained in July, 1875. They were in the air-dried condition. The following results were obtained on analyzing them.

Fresh tans :	I.	III.	V.	Mean of the 3 Analyses.
Water, expelled at 105° to 110°C.	12.34%	11.20%	11.87	11.80
Ash	1.66	1.39	1.74	1.57
Phosphoric acid (P_2O_5) . . .	——	0.0428	0.0358	0.0393
Potash (K_2O)	0.1423	0.1310	0.1055	0.1263
Nitrogen	0.111—0.158	0.200	0.225—0.235	0.186

* Abies Canadensis of Michaux.

Percentage of : —

Phosphoric acid in the ash . .	2.37	3.08 *	2.06 *	2.50
Potash * ,, . . .	8.57	9.43	6.07	8.02
Lime ,, . . .	41.81	——	——	——
Silica and sand ,, . . .	2.08	——	——	——
Ash in the anhydrous materials	1.89	1.57	1.97	1.81

Spent tans:	II.	IV.	VI.	Mean of the 3 Analyses.
Water, expelled at 105° to 110°	15.06	13.27	13.66	14.00
Ash	1.77	1.59	2.03	1.80
Phosphoric acid	0.0316	0.0398	0.0383	0.0366
Potash	0.0564	0.0902	0.1049	0.0838
Nitrogen	0.099—0.139	0.165	0.200	0.1613†

Percentage of : —

Phosphoric acid in the ash * .	1.79	2.51	1.89	2.06
Potash * ,, . .	3.19	5.68	5.18	4.68
Ash in the anhydrous materials	2.08	1.83	2.35	2.09

SPENT SUMACH AND LOGWOOD.

VII. A large sample of spent sumach from Nath. R. Leman, Jr., morocco manufacturer of Chelsea, Mass. It was brought to the laboratory in the actual tub or vat in which the powdered material ‡ had been percolated, the tub and contents weighing more than a hundred pounds. The sample was still very wet, and it gave a decided acid reaction to test paper. It had been leached with water acidulated with sulphuric acid. Dried at 100°, a quantity of this wet material gave off 69.89% of water.

VIII. Finely ground, fresh logwood, obtained from the Boston Dyewood and Chemical Co.

IX. Finely ground, spent logwood, obtained as above.

The following results were obtained on analyzing these substances, —

* The items marked with an asterisk have been calculated from the amounts of phosphoric acid and potash found in the nitric acid solutions of the tans, to be described hereafter, under "Methods of Analysis," and from the weights of total ash obtained on burning the tans.

† Stœckhardt, in his Chemische Ackersmann, 1855, 1. p. 192, § 87, reports a quarter of one per cent of nitrogen in spent tan (perhaps from oak bark), obtained at Tharand in Saxony.

‡ Leaves and young branches of Rhus Coriaria.

	Spent Sumach. VII.	Fresh Logwood. VIII.	Spent Logwood. IX.
Water, expelled at 110° .	30.84 *	21.67	27.66
Ash	12.17	1.89 †	2.69 †
Phosphoric acid	0.1231	0.0233	0.0109
Potash	0.3000	0.0593	0.0230
Nitrogen { Several determinations }	{ 0.995 { 1.065	{ 0.1000 { 0.1271 { 0.1565	{ 0.1409 { 0.1415 { 0.1640
Percentage of:—			
Phosphoric acid in the ash ‡	1.01	1.23	0.404
Potash ‡ ,,	2.47	3.14	0.854
Silica and sand ,,	10.09	2.14	3.79
Ferric oxide, &c. ,,	——	1.19	2.02
Lime ,,	23.03	48.37	56.73 §

X. Spent chip logwood, a very much coarser material than the foregoing, from the same factory.

XI. Ashes obtained in the large way at the works of the Boston Dye-wood and Chemical Co., by burning wet, spent chip logwood, in the furnace of Moses Thompson. ‖

	X.	XI.
Moisture	40.03%	0.12%
Sand and silica in the ash . . .	1.60	5.03
Carbon ,, . . .	——	2.19
Ferric oxide, &c. ,, . . .	1.03	——
Lime ,, . . .	54.52	56.61 ¶

* As here examined, the sumach was air-dried.

† If the samples had been taken in the anhydrous condition, *i.e.*, dried at 110°, the spent logwood would have yielded 3.72% of ash and the fresh cut wood 2.42%. By actual experiment, a second portion of the fresh cut wood dried at 100° to 105° gave 2.28% of ash.

‡ Calculated from the nitric acid solution, as before.

§ A considerable proportion of the lime in the ash was in the state of quicklime (see beyond), though most of it was in the state of carbonate of lime.

‖ Described in "American Journal of Science," 1860, **30.** 248.

¶ A comparatively large proportion of the lime in these ashes existed there in the state of quick-lime. In an experiment, made for another purpose, where some of the ashes were soaked with a definite quantity of water, and the filtrate from the mixture was tested with a standard acid, enough caustic lime was found to amount to 5.4% of the ash, and since there was as much lime in this solution as the water could hold dissolved, it was plain that the amount of quick-lime in the ashes must be larger than the amount which this experiment had exhibited.

I was at first inclined to attribute the presence of quick-lime in the ashes to the high temperature which prevails in the Thompson furnace; but, it appears

Potash	——	0.46 *
Phosphoric acid	——	0.21 *
Nitrogen	0.12—0.12	——
Ash	2.12	——

Methods of Analysis. Several handfuls of the spent tan or dye-wood were ground to fine powder in a drug-mill, in order to obtain a fair sample of the material. Moisture and ash were determined in a special portion of the powder, by drying and burning in a platinum dish; and nitrogen by means of soda lime, using the very finely powdered woods. Phosphoric acid and potash were determined as follows : 40 grammes of the powder were placed in a tall beaker which was covered with an inverted funnel. Rather more than enough strong nitric acid to cover the powder was poured into the beaker, and the mixture was heated for many hours, until, on addition of a fresh portion of the acid, no further decomposition of the organic matter could be perceived. The acid liquor was diluted with water and filtered, and the residue upon the filter dried, and burnt in a platinum dish. Its ashes were dissolved in nitric acid, and the solution added to the filtrate, which was then diluted to the volume of half a litre. Two 200 cc., portions of the liquid were measured out for the analysis. In one of these portions, phosphoric acid was estimated by the molybdenum process, after the liquid had been evaporated to dryness, ignited with carbonate of soda and nitrate of potash, and again dissolved. In the other portion, potash was estimated as chloroplatinate

that Bœrhaave and Wiegleb (see his "Chemische Versuche über die alkalischen Salze," Berlin, 1781, pp. 83, 85) have both noticed that lime-water is obtained on treating the ashes of spent woods with water. So, too, ashes prepared in the Bussey laboratory by burning spent logwood in a muffle, and thereafter calcining the ashes in a platinum dish to destroy a small trace of carbon that had escaped combustion, contained a considerable proportion of quicklime, as has been stated in the note on page 28. That the ashes of spent woods are apt to contain much carbonate of lime was hinted by John ("Ernährung der Pflanzen," p. 56), and proved by De Saussure ("Recherches," pp. 293, 297); a part of this carbonate would naturally suffer decomposition at no very intense heat, and since the ashes contain little or no carbonate of potash, the quicklime thus formed would readily dissolve as such on the addition of water.

* The small proportion of potash and phosphoric acid in the ashes of the spent dye-wood is a point of considerable practical importance, with regard to the use of this substance as fuel. The wet material can, in fact, be burnt very advantageously in the Thompson furnace, for heating steam-boilers, since its ashes do not attack the grate-bars. But with spent tan, the furnace gives less favorable results, and one, if not the sole, reason of this difference is to be found in the fact that the ashes of the spent tan, which still contain considerable quantities of potash and phosphoric acid corrode the grate-bars of the furnace. These bars, though made of the most refractory fire-clay, are exposed to intense heat, and are consequently peculiarly liable to suffer from the action of an alkaline flux.

of potassium, after the liquor had been evaporated to dryness with ferric nitrate, and ignited to decompose the latter (see this Bulletin I., 195). The sulphuric acid was removed by means of chloride of barium in every instance, and the excess of baryta was got rid of in its turn by means of carbonate of ammonia.

By using nitric acid to decompose the organic matter, all risk of losing either phosphoric acid, or potash through volatilization, when preparing ashes, is done away with. Compare Vol. I. p. 199. The idea of using nitric acid for this purpose is not new. It has been thus applied by Marggraff, John's " Ernährung der Pflanze," p. 21; by Sorby, "Philosophical Magazine," 1847, **30.** 330; by Caillat, " Comptes Rendus," 1849, **29.** 137; by Arendt, in his " Wachsthum der Haferpflanze," 1859, p. 29, and doubtless by others.

Silica, lime, and oxide of iron, &c., were determined according to the usual methods in the ashes of the· several materials, special portions of ash having been prepared for the purpose by burning the substances in a muffle.

I am indebted to my assistant, Mr. J. Andrew Henshaw, for most of the analyses recorded in this paper.

It appears from the foregoing analyses, that, in the case of tan, there is about as much phosphoric acid in a given weight of spent bark, as there is in the bark which has not been leached; that a considerable amount of the original potash is washed out, together with the tanning materials; and that the proportion of nitrogen remains essentially unchanged. D'Arcet * found no soluble alkali whatsoever in the ashes of cakes of spent tan (*mottes*), that had been prepared for use as fuel. Berthier,† on examining similar cakes (*mottes*) of spent tan from oak-bark, found 12% of ash "that was obviously mixed with sand." "These ashes yield only 1.6% of soluble alkalies, and are consequently never employed for making lyes. It is evident that more than half the alkaline substances in the original bark have been removed by the water during the process of maceration in the tanpit." In fresh tan (oak-bark), Berthier found 6% of ash, which contained 5% of soluble salts.

In the case of finely ground logwood, less than half as much potash and phosphoric acid were found in the spent materials as in the fresh wood; while, in their ashes, the disparity is still more strongly marked. The proportion of lime in the ash of the spent wood is noticeably larger than in the other ash.

* "Annales de Chimie," 1811, **79.** 152.
† "Annales de Chimie et de Physique," 1826, **32.** 250.

In the leached sumach, also, the proportion of potash and phosphoric acid was very small, as compared with the amounts that are ordinarily found in the leaves and twigs of plants. See the table on page 207 of this Bulletin, Vol. I.

Other analyses of spent woods have been published, as follows : — According to R. Hoffmann,* a sample of spent Brazil wood contained 0.823% of nitrogen, and 0.4% of ashes, which contained lime, magnesia, and traces of phosphoric and sulphuric acids, and of potash, soda, and oxide of iron. Stœckhardt † had previously stated, that spent logwood and spent Brazil wood are exceptionally rich in nitrogen, and had, on that account, recommended them as good materials for making compost; an idea which was copied by Heiden ‡ in his very carefully prepared treatise on manures. According to Stœckhardt, the proportion of nitrogen amounted to 2.8% in logwood, and to 2.5% in Brazil wood. He reports further 4 to 5% of ashes, consisting of lime for the most part, with small quantities of potash, and sulphuric and phosphoric acids.

It will be observed that, with respect to the amount of nitrogen in spent dye-woods, the results of Stœckhardt and Hoffman, just cited, disagree totally with the results obtained in this laboratory. My experience is not only that the proportion of nitrogen in all the spent materials examined is small, but that it is particularly small in the case of logwood. In the face of testimony like the above, coming from two different chemists, I have naturally taken pains to test the question with special care. Each of the determinations of nitrogen, in the fresh and spent logwood, was repeated by a second analyst ; so that the figures which I have given above represent results obtained by two separate chemists, working entirely independently of one another. I have been unable to detect any thing which should lead me to believe that the spent dyewoods can ordinarily contain much nitrogen.

It is not at all probable, in the first place, that heart-wood, such as logwood is, would be specially rich in nitrogen. There is evidence, indeed, to be adduced hereafter (page 42), which goes to show that, on partially leaching various vegetable matters with water, the proportion of nitrogen in the leached product may sometimes be found to be

* In his "Jahresbericht über Agrikultur-Chemie," 1860–61, 3. 185.
† In his "Chemische Ackersmann," 1858, 4. 240.
‡ "Düngerlehre," 1868, 2. 414.

larger than it was in the original material; for since many of the non-nitrogenized constituents of plants — such as the acids, sugars, coloring matters, and some gums — are more soluble and more diffusible in water than most of the nitrogenous matters that are found in plants, the non-nitrogenous matters might sometimes be washed out first, and in larger amounts than the nitrogenous matters, when the plants were exposed to the action of water. The fact that there is so little difference between the amounts of nitrogen found in the fresh and spent barks and woods, as given above, points, indeed, to this same conclusion. But it is plain that, in order that any very large proportion of nitrogen may accumulate in the leached product, the original wood must itself be tolerably rich in this element; and I am wholly unable to find that there is much nitrogen in freshly ground logwood. My friend, Mr. C. E. Avery, was good enough to have some logwood cut into small fragments, at the factory, under his own eye, and to bring me immediately a considerable quantity of the material, which he regarded as a very fair sample of fresh-cut wood. It was examined next day for nitrogen, with the following result: —

Moisture expelled at 110° 12.31%
Nitrogen . . . . 0.121 — 0.155%
Or, nitrogen in the fresh logwood, dried at 110°, . 0.138 — 0.177%

A portion of this new sample of logwood was afterwards placed in a burette, and percolated with distilled water until the water came through colorless. The wood thus thoroughly leached was then dried and subjected to analysis. There was found: —

Nitrogen in the percolated wood, dried at 110°, 0.172 — 0.238%.

The proportion of nitrogen in various strongly dried woods has been given by Chevandier,[*] as follows: — Aspen, fir, willow, hornbeam, and birch, from 0.81 to 0.88%. Oak, beech, alder, and spruce, from 1.04 to 1.15%. But even these results seem unduly high in comparison with those of Boussingault and Payen,[†] who found 0.54% of nitrogen in oak sawdust, 0.16 to 0.23% in fir sawdust, and 0.23 to 0.29% in acacia sawdust, all taken in the air-dried state; or 0.72%; 0.22 to 0.31%; and 0.31 to 0.38%, respectively, in the thoroughly dried condition. So, too, Stœckhardt[‡] reports only 0.3% of nitrogen

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[*] "Jahresbericht der Chemie," 1847–48, 1. 1098, note.
[†] "Annales de Chimie et de Physique," 1841, 3. 102.
[‡] In his " Chemische Feldpredigten," 1856, 2. 110.

in pine sawdust, and 0.6% in spruce twigs picked out from the rakings of woodland.

All of which goes to show that spent dye-woods are poor in nitrogen, and on that account peculiarly ill fitted for making compost.

With regard to ash ingredients, it would naturally be expected that spent tan would retain a larger proportion of phosphoric acid, and potash also, than could be held by leached logwood; since, during the growth of a tree, there is, ordinarily, a certain tendency to the accumulation in the bark of insoluble or difficultly soluble forms of inorganic matter.* But even with the barks, it is noteworthy how small a proportion of the fertilizing materials is left after the process of leaching. In respect to phosphoric acid, indeed, the ashes of spent tan are as rich as ordinary wood-ashes, but the proportion of potash contained in the ashes of spent tan (less than 5%) compares very unfavorably with the average amount (8½%) in wood-ashes from house fires. The remark of Berthier, cited on page 233 of the first volume of this Bulletin, that the ashes of fresh tan (oak-bark) contain a mere trace of phosphoric acid, is probably incorrect. Compare the result obtained by Eckert, as cited on the same page.

From the analyses, it appears that ashes obtained by burning spent sumach would be but little better, as a manure, than leached wood-ashes, and that the ashes of spent logwood chips would hardly be as good as leached wood-ashes, were it not that they have the merit of being perfectly dry. As with leached wood-ashes, so with the ashes of the leached wood now in question, their fertilizing action is to be attributed, for the most part, to the carbonate of lime, of which they chiefly consist.

The foregoing results agree with those of previous researches. It has been shown repeatedly by chemists that a large proportion of those ash ingredients of woods and herbaceous plants that are soluble in water, when in the form of ashes, may be removed by leaching the wood itself, or the herb. The experiments of Bœrhaave and of Stahl exhibited this fact as long ago as the beginning of the eighteenth century; and the work of these chemists was carefully reviewed and confirmed by several of their followers, notably by Wiegleb,† who made many experiments on the subject.

* Compare De Saussure, in his " Recherches Chimiques sur la Végétation," 1804, p. 287; and Johnson's " How Crops Grow," p. 190.

† In his " Chemische Versuche über die alkalischen Salze," Berlin, 1781, pp. 79-84, 70.

From fresh beech-wood, for example, Wiegleb obtained 1% of ashes; and, in these ashes, he found 16.28% of salts soluble in water, or 16.09% of carbonate of potash; while upon the other hand, he found that he could leach out 0.67% of ash ingredients from beech-wood saw-dust by boiling it repeatedly with fresh portions of water, and squeezing the mass in a press after each of the boilings.   One half of the weight of the ashes of the filtered extract in question were still soluble in water, after the organic matters of the extract had been destroyed by ignition.   From the ashes of the leached saw-dust, Wiegleb got no alkali salt, on digesting with water; but, on evaporating this water, he obtained four grains of residue (from the ashes of two pounds of the leached wood), which consisted of carbonate of lime and a trace of sulphate.   Most of this lime had dissolved as caustic lime, as Wiegleb is at pains to show.

So, too, Marggraf * obtained 50 grains of ashes and 10 grains of potashes (i.e., salts soluble in water) to the pound of beech-wood proper; while from leached beech-wood he got only 37 grains of ashes and 3 grains of potashes for each pound of the material taken.   By the examination of a great variety of herbs, Wiegleb † proved, furthermore, that a considerable proportion of the potash in the stalks and leaves of plants may usually be extracted by means of water.   Similar results were obtained by John ‡ also, who worked upon elder pith, the pith of sunflower stems, and the needles of coniferous trees.   Operating upon the pith of dry sunflower stalks, he found that it gave 3.51% of ash, more than half of which was soluble in water; but on leaching a quantity of the pith with water, and burning the residual pith, he got only 1.27% of ash, which consisted of "carbonate and phosphate of lime, together with some oxide of iron, and traces of potash."   Among the matters that had been dissolved from the pith by the water, he found a comparatively large amount of saltpetre, as well as some chloride, sulphate, phosphate, malate, and citrate of potassium.   He found, moreover, that the proportion of alkali in the fresh pith, taken by itself, was much larger than it was in the whole stem; i.e., when the pith and shell were taken together.   With elder-pith, on the contrary, he got a different result.   By means of water alone, he was unable to dissolve any considerable proportion of alkali from the pith, though on using acidulated water he extracted the potash wellnigh completely.

De Saussure § found, like his predecessors, that less ashes can be got from leaves that have been washed repeatedly with water than from the unwashed materials.   He proved anew that the alkali-salts are removed in larger proportion from plants by such washing than the other ash ingredients, and that, next to the alkali-salts, the phosphates of lime and

* Cited in Leuchs, "Der Potaschen-Fabrikant," Nürnberg, 1844, p. 26.

† Op. cit., pp. 110-124.

‡ See his "Ernährung der Pflanzen," Berlin, 1819, pp. 54-61.

§ In his "Recherches Chimiques sur la Végétation," 1804, pp. 279, 287, 293, and 297.

magnesia dissolve most readily. Carbonate of lime, on the contrary, as he insists, remains undissolved; so that the proportion of it in the ash of a leached plant will be larger, through mere subtraction of the other inorganic constituents, than in the ash of the original plant. Leaves of the hazel-nut, gathered in May and dried at 25° C., gave De Saussure 6.1% of ashes, which contained in every 100 parts, 26 parts of salts soluble in water (mostly carbonate of potash), 23.3 parts of phosphate of lime and magnesia, and 22 parts of carbonate of lime; while from similar dried leaves that had been simply washed several times with cold water, and again dried, he got 5.7% of ashes, that contained, for every 100 parts, 8.2 parts soluble salts, 19.5 parts phosphates of lime and magnesia, and 44.1 parts of carbonate of lime. Four per cent of silica was found in the ash of the washed leaves, against 2.5% in the ash of the fresh leaves. So, too, an "extract" obtained by De Saussure, by boiling oak saw-dust in water for half an hour, and evaporating the soluble matter to dryness at a moderate heat, gave 6.1% of ashes, of which 51% was soluble in water.

Calvert * noticed that both phosphoric acid and magnesia can readily be washed out from cotton fibre, and from various seeds, by means of hot water. From a number of samples of pure cotton, he dissolved, besides magnesia and some lime, about 0.05% of phosphoric acid; while only a trace of that substance could be found in the ashes of the cotton that had been leached. From wheat, and from French beans in the pod, hot water dissolved a large quantity of phosphoric acid and magnesia; and these substances were found also in water in which the kernels of walnuts and other nuts had been steeped for forty-eight hours. These results are interesting, not merely from their coincidence with the observed fact that the ashes of leached woods consist chiefly of carbonate of lime, and are poor in phosphates, but from their agreement with the observation of De Saussure ("Recherches," p. 293), that "when a plant is washed with water, the phosphates of lime and magnesia are removed by this liquid in larger proportion than any other of the components of the ashes, excepting the alkali-salts."

It was recognized, very long ago, as a matter of practical experience, by potash-makers in Europe, that fire-wood which had been exposed to the action of water, as when floated or rafted upon rivers, and that straw and leaves which had been exposed to rain, gave ashes that contained decidedly less potash than the ash obtained from the original dry materials.† In confirmation of this view, D'Arcet‡ found in 100 grammes of ashes from new wood, that had been burnt in an ordinary chimney, enough soluble alkali to mark 11.6° of an alkalimeter, while floated wood, burnt in the same chimney, gave an ash that marked only 4.85°.

* "Journal of London Chemical Society," 1867, 20. 308.
† Compare Leuchs, "Der Potaschen-fabrikant," p. 26.
‡ "Annales de Chimie," 1811, 79. 151, note.

It is probable that a considerable amount of evidence relating to the matter now in hand might be accumulated by studying the records of some of the earlier analyses of hay and other kinds of herbs and fodders, since the thorough lixiviation of the dried plants with water was an essential feature of several of the older methods of analysis, and it must have happened that the composition of a very considerable number of leached plants was thus determined incidentally. But the task would hardly repay the trouble of it, and it will be better, on many accounts, to refer instead to another set of results, bearing directly upon the present inquiry, that have been obtained by the chemists who have studied the action of water upon tea-leaves and the coffee-berry.

It appears from a multitude of experiments that the ashes of tea, taken in its ordinary air-dried commercial state, amount, on the average, to about 5.75% ; * or to nearly 6% of the absolutely dry tea. From 53

* According to the recent averages of Wanklyn and of Allen. That the ash of tea leaves is a remarkably constant quantity will appear from the following table, in which the names of observers and some other items relating to the text have been incorporated.

Name of observer.	Ash in air-dried tea.	Proportion of the ash soluble in water.	Extract, dissolved by water.	Spent leaves (air-dried).
1.			36–41% (green). 35% (black).	56–57%. 65%.
2. -	5.28	(Mean of 4 samples).	50.81 (green, 2 exps.) 44.4 (black, 2 exps.)	
8.	5.56 (4 ,,)		48.4 (green, 10 exps.) 88.4 (black, 18 exps.)	
4.	5.48 (5 ,,)			
5.	5.60 (5 ,,)			
6.	5.63 (1 ,,)		36.26 †	53.83 †
7.	5.68 (40 ,,)	52.82	36.25 (green, 8 exps.) 31.92 (black, 15 exps.)	
8.	5.75 (6 ,,)	59.97		
9.	5.66 (9 ,,)	53.00		
10.	5.75 (10 ,,) .	58.09		50 green. 60 black.
11.	4.98 (8 ,,)		42¼	

1. Brande, "Quarterly Journal of Science," 1822, **12.** 201.
2. Mulder, "Poggendorff's Annalen," 1838, **43.** pp. 169, 648.
3. Peligot, "Annales de Chimie et de Physique," 1844, **11.** 145.
4. Horsford's pupils, "American Journal of Science," 1851, **11.** 249.
5. Warrington, "Edinburgh New. Phil. Journal," 1851, **51.** 249.
6. Zœller, "Annalen der Chemie und Pharmacie," 1871, **158.** 180.
7. Wigner, "Pharmaceutical Journal and Transactions," 1873–74, **4.** pp. 909, 952.
8. Wanklyn, "Chemical News," 1873, **28.** 187.
9. A. S. Wilson, "Chemical News," 1873, **28.** 307.
10. A. H. Allen, "Chemical News," 1874, **29.** 189.
11. Hodges, "Chemical News," 1874, **30.** 115.

† " Not completely extracted."

to 60% of this tea-ash proper is soluble in water, and the composition of the original ashes has been determined as follows:—

	Spooner.[*] I.	Hague.[*] II.	Zœller. III.
Potash	40.51	30.84	39.22
Soda	2.56	10.67 (?)	0.65
Lime	7.90	7.43	4.24
Magnesia.	7.58	6.17	6.47
Oxide of iron	6.13	4.32	4.38
Phosphoric acid. . . .	10.33	15.12	14.55
Sulphuric acid	6.27	4.40	trace.
Chlorine	0.91	1.99	0.81
Silica, sand, and charcoal .	15.31	15.88	4.35
Carbonic acid	2.26	8.83	24.30
Oxides of manganese . . .			1.03
	99.76	100.65	100.00

In thirty-six samples of ash, from unadulterated teas, Wigner (as cited in the note) found amounts of alkali soluble in water that, calculated as potash, ranged from 22.89% to 33.10% of the total ash, and from 43.33% to 62.67% of the soluble portion of the ash; or, on the average, to 23.52% of the total ash, and 54% of the soluble part of the ash.

On thoroughly leaching tea, that is to say, on boiling the commercial article repeatedly in fresh quantities of water, till the liquid no longer becomes colored, the spent leaves will amount, when air-dried, to about 50% of the original, in case it was green, or to about 60% if the tea was black (Allen). The air-dried spent leaves contain only from 1.6% of ash (Hodges), to 4.3% (Allen). Dried at 100°, they contain 3.06% of ash (Zœller). Only 12.1% of the ash of the leached leaves is soluble in water (Allen). The composition of the ashes of spent tea leaves, and of the extract obtained from tea leaves by means of water, have been determined as follows:—

	Ash of spent tea leaves. (Zœller.)	Ash of extract of tea. (Zœller.)	Ash of extract of tea. (J. Lohmann.[†])
Potash	7.34	55.15	47.45
Soda	0.69	0.68	6.94
Magnesia	11.45	3.13	6.84
Lime	10.76	0.95	1.24
Oxide of iron.	9.53	1.73	8.29
Manganese Oxides . . .	1.97	0.43	0.71
Phosphoric acid	25.41	7.89	9.88
Sulphuric acid	trace	trace	8.72
Chlorine	trace	0.81	1.70
Silica and sand	7.57	2.92	8.40
Carbonic acid, &c. . . .	25.28	26.31	10.09
	100.00	100.00	100.26

[*] "American Journal of Science," 1851, **11.** 250.
[†] Liebig's "Chemische Briefe," 1859, **2.** 182.

Zœller found 11.46% of ash in his tea extract, dried at 100°, and J. Lehmann, 16.09% in his sample. Wigner, whose results appear to refer to the original tea, and not directly to 100 parts of the dry extract, found from 3% to 6.44% of ash, or 4.28% on the average, in the extracts from 18 samples of unadulterated teas examined by him.

As for nitrogen, Peligot found from 5.1 to 6.6% of that element, in four samples of tea, dried at 110°. Zœller found 5.4% in a sample of air-dried tea, and Hodges 4.7 and 4.4% in two samples. In spent leaves, upon the other hand, that had been dried at 110°, Peligot found in two samples, 4.3 and 4.5% of nitrogen, while Zœller found 3.5% in his not completely spent leaves, dried at 100°, and Hodges 2.1% in his second sample, above mentioned. In the "extract" from tea leaves, dried at 110°, Peligot found 4.4 and 4.7% of nitrogen, while Zœller found 10.09% of nitrogen in his single specimen dried at 100°. Kraus (Jahresbericht der Chemie, 1872, p. 805) found 2.8% of nitrogen in a dried extract (incomplete) that amounted to 23.5% of the original tea, and in the partially spent leaves he found 3.58% of nitrogen.

It is interesting to observe that several of these experimenters have insisted that many washings are necessary in order to exhaust tea leaves completely of their soluble matters. Thus, Brande urged, that it must not be supposed that, in the ordinary process of making tea, the leaves are completely deprived of matters soluble in boiling water. "On the contrary, from tea leaves in the state in which they are usually thrown away there is still contained from 10 to 14% [or more] of soluble matter." Mulder, who got from 50 to 52% of soluble matter from green teas, and 42 to 47% from black teas, on extracting them thoroughly with water, obtained a much smaller product when the lixiviation was less thorough. On boiling each of twelve different teas four times, with equal volumes of water, it appeared that black teas yielded only from 29 to 36.7% of extract, and the green teas from 35.3 to 44.4%. Peligot (page 147) has dwelt upon the subject in somewhat similar terms; and Allen found, for his part, that by operating upon powdered tea, a considerably larger proportion of the material can be dissolved in water than when whole leaves are boiled. From whole leaves he got 50% (green) and 60% (black), as has been said, but from pounded green tea he got only about 42% of dry spent material, and from pounded black tea about 49%. Allen found, moreover, that when black tea leaves, that have been infused, as in the ordinary process of tea-making, are allowed to dry in the air, and then boiled repeatedly in water, the dried spent product will amount to from 78 to 85% of the weight of the leaves taken, in case the leaves have not been broken; but, on pounding the leaves before boiling, the spent product will amount to no more than from 72 to 75%. From spent leaves of commerce that gave a total ash of 3.53%, of which 2.27 parts in a 100, were soluble in water, Wigner obtained 8.53% of dry extract, which in its turn yielded 1.53% of ash.

In respect to coffee, Schrader * found that broken unroasted berries, that were boiled several times with water, yielded 21.85% of dry extract and 66.67% of sharply dried residue. From roasted and powdered berries, he got 28.75% of extract, and 68.75% of dry residue. He found 3.91% of ashes in the original unroasted berries, and that 33⅓ per cent of this ash was carbonate of potash. Levi found 3.19% of ash, and Herapath 3.30%, containing 40.81% of matters soluble in water. Allen † found 4% of ash on the average, and that 81% of the ash was soluble in water. J. Lehmann ‡ has analyzed an extract obtained by partially exhausting roasted coffee with water, as follows: 100 parts of the boiled berries yielded 21.52 parts of dry extract containing 16.6% of ashes (or 3.41% of the roasted coffee taken). 100 parts of the extract contained : —

	Extract of coffee.	Graham and others (Bussey Bulletin, 1. 216) found in the ash of the coffee berry.
Potash	52.70	51.52 to 55.80
Lime	3.58	
Magnesia	8.67	
Oxide of iron . . .	0.25	
Phosphoric acid . .	10.02	10.15 to 11.60
Sulphuric acid . .	4.01	
Silicic acid	0.73	
Carbonic acid . . .	20.50	14.74 to 18.13
Sand and charcoal .	0.49	
Chlorine	0.94	

That is to say almost the whole of the potash and of the phosphoric must have passed into the extract and have left the leached berry. This consists with the observation of Berard,§ who found in coffee-grounds: —

	Ashes.	Phosphoric acid.	Nitrogen.
When in the air-dried state	1.50%	0.24%	0.273%
,, anhydrous ,, ...	5.00	0.80	0.910

The large amounts of potash and of phosphoric acid that are dissolved from plants by water, and the small amounts of these substances that are left in the spent plants, point to the conclusion not only that the thoroughly washed plants can have but little fertilizing power in respect to these ash ingredients, but that the mere leaching of fallen leaves, or mown weeds or hay upon a field, may add to the land an appreciable amount of manure.

* Gehlen's "Journal für Chemie, Physik, und Mineralogie," 1808, 6. pp. 553, 556.

† "Chemical News," 1874, 29. pp. 140, 190.

‡ Liebig's "Chemische Briefe," 1859, 2. 182.

§ Hoffmann's "Jahresbericht über Agrikultur-Chemie," 1859–60, 2. 218.

Certain experiments of Hellriegel, on the composition of sap that was pressed out from clover plants of various ages, are not without interest in this connection, inasmuch as they indicate, in still another way, the fact that continuous washing is necessary in order to remove all the soluble matters of a plant.   It was found, for example, that the expressed sap of young clover plants held in solution a much larger proportion of several of the ash ingredients, than the sap from old plants.   Thus in the sap from young plants, there was found fully three-quarters of all the potash, that the entire plant contained, two-thirds of all the lime, half the chlorine, and not quite half of the magnesia; while of phosphoric and silicic acids, only about one-quarter of the whole amount was found in the expressed sap.   In older plants, of the second year's growth, Hellriegel got from the sap more than half of all the lime that was contained in the plants, and often as much as two-thirds of it; but he rarely found in the sap of these older plants as much as half of the entire potash, and, on the average of several experiments, he got only about one-third of that substance.   So, too, a smaller proportion of the phosphoric acid and the silica was usually found in the sap of the older plants, while of magnesia he found in such sap some 80 or 90% of all that the plants contained..   Almost the whole of the chlorine, also, was found in the sap of the old plants.   Hellriegel satisfied himself by special experiments, upon thoroughly leached clover plants, that this retention of potash, in particular, by the expressed stem and leaves of the older plants is not due, or at the least not to any great extent, to the deposition of insoluble compounds of potash within the plant.   He inclines rather to the belief that certain kinds of cells, in particular parts of the plant, have become so firm and tough through age, that they resist the crushing action of the press, and retain the sap that was within them, as well as the potash, or what not, that the sap holds dissolves, while in the young plant all kinds of cells break readily, on being subjected to pressure, and give up their liquid contents.   In this sense, Hellriegel supposed that the sap obtained from the older clover plants may have come, for the most part, from the softer parts of the tissue, and that it was not a fair sample of all that was actually contained in the plant.   Difficulties analogous to this would, of course, be encountered in leaching any vegetable fibre, though they could be more fully overcome by the process of leaching than by that of mere pressing, because of the power of repeating the application of a solvent as often as may seem fit.

In his well-known research upon the growth of the oat-plant, Arendt [*] endeavored to extract the whole of the soluble matters from the pulverized, dry, ripe plants, by percolating the fine powder systematically with water.   He found it impossible to obtain any useful results by experimenting in this way upon the grain, but from the leaves and stems he dissolved out very considerable quantities of the ash ingredients.   He

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[*] "Das Wachsthum der Haferpflanze," Leipzig, 1859, pp. 166-187.

found, indeed, that the whole of the chlorine and of the sulphuric acid, and nearly all the phosphoric acid, could be washed out from the leaves and stalks, and that the larger share of the lime, magnesia, soda, and potash, also was soluble, though a portion of each of these substances escaped solution. Iron compounds were found both in the solution and in the leached plants. Silica was insoluble for the most part, though a little of it passed into the solution. A good statement of the difficulty of extracting all the soluble ash ingredients from a plant by means of water has been given by Hellriegel,* in connection with the work just now referred to.

Several chemists have investigated the composition of hay that has been exposed to rain in the making, as compared with that of hay that has been cured in fine weather. The results of these experiments do not agree with one another very closely, as was naturally to be expected from the dissimilarity of the conditions under which the experiments were made. It is hardly conceivable, for that matter, that the hay in any two experiments of this sort could have been leached by rain to precisely the same degree, or have undergone either the same amount of drying before it was first wet, or the same amount of decay and fermentation before the final wetting. Hence, although the experiments have a certain bearing upon the present inquiry, they are of less importance for it than many of those already given that have been carried out in a more systematic way. In a case reported by Stœckhardt,† a quantity of grass that had been cut on a given day was made into hay of excellent quality in the course of three days. Part of it was safely housed on the third day, while the rest was caught out in a severe shower, and, after it had been again spread, was exposed to alternate wettings and dryings, until the thirteenth day after mowing, when it was housed in its turn. Analyses of the two sorts of hay gave the following results : —

There was contained in the : —	Well-made hay.	Damaged hay.
Albuminoids that were still soluble in water . .	7.8	6.5
Carbohydrates ,, ,, ,, . .	54.0	49.8
Cellulose and other insoluble organic matter .	32.1	36.5
Ashes	6.1	7.2
	100.0	100.0

Ritthausen,‡ on the other hand, operating upon red clover that had been mown on June 6–8, just as it was beginning to blossom, and which was leached by heavy rains that fell upon it almost every day during two weeks, as it lay upon the field, found : —

* " Die landwirthschaftlichen Versuchs Stationen," 1862, **4.** 31.
† In his " Chemische Ackersmann," 1855, **1.** 60.
‡ " Journal für praktische Chemie," 1855, **65.** 18.

	In good clover hay, mown June 2.	In the hay of the leached clover.
Water	16.00	16.03
Albuminoids	14.59	15.85
Carbohydrates	36.12	23.38
Cellulose	25.25	37.24
Ashes	8.04	7.50
	100.00	100.00

In this case the damaged hay contained considerably less ashes than the well-made hay. It appears, moreover, that a larger proportion of carbohydrates than of albuminoid substances were removed by the water; the percentage of albuminoids as well as that of cellulose in the damaged hay having been increased by this subtraction of the carbohydrates. Ritthausen insists that, to all appearance, his leached clover was still tolerably well-preserved; the leaves and stems retained a pale green color, and no traces of decomposition were visible.

Beyer,[*] for his part, examined hay made from the kidney vetch (*Anthyllis vulneraria*), one sample of which was cured in dry weather, while the other had lain for three weeks exposed to rain. There was contained in 100 parts of the dry substance of the: —

	Well-made hay.	Damaged hay
Albuminoids	11.87	8.66
Carbohydrates	42.59	45.74
Fat	3.22	1.01
Cellulose	36.20	39.87
Ashes	6.12	4.72

In this case, where the exposure to washing and to decay was long continued, the loss of albuminoids was large, 27% of these ingredients having decomposed and gone to waste. In all such cases, the amount as well as the kind of decomposition must be determined in great measure by the thickness of the swathes, or the size of the cocks or beds in which the wet hay is lying. As is well known, the risk of decomposition is generally speaking greater in proportion as the heap is larger when the hay has become soaked with rain. According to Beyer, the albuminoid matters pass into a state of decomposition when they dissolve, and then act as a ferment to decompose the carbohydrates. Beyer found that much potash, phosphoric acid (nearly $\frac{1}{4}$), lime, and magnesia (about $\frac{1}{4}$), had been washed out of the hay, and that the proportion of silica and iron oxide in the ashes of the leached hay was large.

Quite recently, E. Schulze [†] has examined two samples of damaged clover hay as follows : The red clover was all mown on the 15th and 16th of June. But one lot was turned on the 17th, and on the 18th it was put upon

[*] Cited in Werner's "Futterbau," Berlin, 1875, p. 189.
[†] "Biedermann's Centralblatt für Agriculturchemie," August, 1876, S. 186.

drying frames (Heu-böcke), where it remained during the rainy weather that persisted during the last half of June, and was housed on the 7th July. The other lot, on the contrary, remained lying upon the field during the entire rainy period. This second lot was turned several times: it was cocked on the 30th June and 2d July, and housed on the 3d July. The composition of the two samples was as follows. In 100 parts of the hay dried at 100 ° or 110 °, there was found : —

	In the hay from the drying frames.	In the hay that lay on the ground.
Albuminoids	13.06	9.56
Carbohydrates (including fat) . .	43.93	36.62
Cellulose	38.05	50.47
Ashes	4.96	3.35
	100.00	100.00
Fat (*i.e.* ether extract)	2.80	1.89
Substances still soluble in water .	32.33	18.00

From the analysis, it appears that the hay cured upon the drying frames was not very severely damaged. It would still be classed as clover hay, though its composition is distinctly inferior to that of normal clover hay as given in the tables of fodder values. But the hay that lay upon the ground was of very bad quality. Both samples contained a smaller proportion of ashes, of albuminoids, and of carbohydrates, than normal clover hay, and a much larger proportion of cellulose; and the remark is specially true of the second sample, that was particularly exposed to fermentation and leaching from having lain unprotected upon the field. It is to be remarked, however, that a larger proportion of leaves and flowers had been lost by rubbing off from the last-named sample, than from the other, because of its having been turned and handled more frequently.

It will be noticed that, in three out of the four sets of analyses above cited, the total amount of ashes is considerably less in the washed hay than in the hay that has never been wet; a result which consists with the experiments upon leaves and herbs that have been described on the preceding pages. It may be accepted as a rule, that a comparatively large proportion of the ash ingredients of fresh leaves and herbs, and, in general, of the young or growing parts of plants may be washed out by means of water. But, as has been seen already from the analyses on page 27, this remark appears not to be true, either of spent logwood or of spent tan-bark. A given weight of either of these leached materials was found to contain more ashes than were contained in a similar weight of the natural wood or bark, though the composition of the ashes was decidedly different in the two cases.

The increase in the proportion of ashes on leaching the barks and heart-wood, that is to say, the older and least vital parts of plants, must depend, in general, upon the insolubility or difficult solubility of a considerable portion of the ash ingredients that are contained in them. It is conceivable, indeed, that it might perhaps be due in part in some instances to the removal, *i.e.*, the subtraction, from the wood or bark of certain organic matters, such as the coloring matters, that might be well-nigh destitute of ash ingredients. In order to test this point, I had a quantity of finely powdered fresh logwood leached with distilled water in the laboratory with the utmost care. To this end, a weighed quantity of the material was placed in a straight burette that had been plugged with a tuft of cotton, and it was there percolated with water, until the drops of water were colorless as they fell from beneath the wood. The apparatus was arranged so that atmospheric air was not in contact with the wood during the percolation. The leached wood was finally dried, and the amounts of ashes contained in it, as well as in the original wood, were determined. The results of this experiment were as follows: —

The fresh wood regarded as having been dried at 110° * gave up 13.04 per cent of its weight to the water.

There was found 2.33% of ash in the leached wood, dried at 110,° and 2.32% of ash in the original fresh wood, dried at 110°. The dried leached wood amounted to 86.96% of the original dried wood.

On evaporating the percolate to dryness at 110°, there was found dry "extract" to the amount of 12.72% of the dry wood taken, and this extract contained 3.74% of ash.

In other words, it was found that 100 lbs. of the original dried wood contained 2.32 lbs. of ashes, and that 2.03 lbs of these ashes were left in the 86.96 lbs. of wood that had been exhausted with water; while 0.47 lb. of ashes was recovered from the solution. The fact that the sum of the last two quantities is slightly greater than the first is due to errors of manipulation, or of observation, such as are well-nigh inseparable from experiments of this kind.

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* As a matter of course, the wood actually operated upon was in its original air-dried state, in order that none of its constituents might be altered before the process of percolation had begun. But the amount of water that could be expelled at 110° was estimated in another portion of the wood, and the weight of this water was subtracted from the amount of the material that had been taken for the percolation.

The amount of nitrogen contained in the percolated wood has been given already on page 32.

As for wood that has been leached with dilute acids, instead of water, it would appear that, although a considerably larger amount of the ash ingredients are dissolved by the acids than by water alone, it is still, practically speaking, impossible to remove the whole of the ashes in this way. Bischof,* for example, on attempting, for purposes of analysis, to extract the alkalies completely from various kinds of woods by long continued boiling with sulphuric acid, was unable to accomplish the wished-for result. The ashes obtained from woods that had been thoroughly leached in this way, still contained some salts of the alkalies. Sacc,† by using muriatic acid, succeeded in removing a very large proportion of the ash ingredients from wood of the silver-fir. Thus, in the original fir-wood sawdust dried at 100 °, he obtained 0.55% of ashes. But on digesting such sawdust with muriatic acid of commerce, mixed with half its weight of water, and afterwards washing with water, and drying the residue at 100°, he got only 0.07% of ashes. It is to be expected, of course, that the acids, particularly muriatic and nitric, would remove a larger proportion of the phosphates from wood than mere water, and that they would dissolve out some of the lime compounds also that are left in the form of carbonate of lime when wood is burnt; and that this is actually the case may be seen from the experiments of Dussance,‡ who exhausted red sandal-wood (*Pterocarpus santalinus*) with water, with alcohol, and with muriatic acid used in succession. In the ash of the matters dissolved by water from the wood, there was found a quantity of carbonate, sulphate, and chloride of potassium and sodium, as well as silica, oxide of iron, and sulphate of lime; the acid, on the other hand, dissolved an abundance of oxalate and phosphate of lime, and some phosphate of magnesia. The wood that had been leached, as above stated, gave 1.84% of ashes, consisting of silica and carbonate of lime. The acid used in these experiments marked 15 ° B.; a quantity of it was left to stand in the cold upon the wood during 24 hours, and was then renewed until the fresh portion ceased to dissolve any thing. From three different samples of unleached sandal-wood, Dussance obtained respectively, 2.03, 2.10, and 4.46% of ashes.

The general conclusion to be drawn from all these experiments is clearly, that leached woods or herbs or leaves or bark contain a very much smaller proportion of fertilizing substances than the, original unleached materials ; and that practically, no matter whether they be fresh or rotten, they have very little real value as manure. This con-

* "Journal für praktische Chemie," 1849, **47. 196.**
† "Annales de Chimie et de Physique, 1849, **23. 223.**
‡ "American Journal of Pharmacy," 1860, **32. 6.**

clusion can be strengthened still further, as regards the leached woods, by considering how small a proportion of fertilizing ingredients are contained in wood in its natural condition. Fresh sawdust, for example, even that from hard woods, can rarely, if ever, be considered an economical manure; since the proportions of all the fertilizing substances, excepting nitrogen, that are contained in it, are so small that they may be regarded as lost in the mass of useless ligneous matter.

The proportion of nitrogen, moreover, that is contained in wood is less than that in turf and in most peats and many pond-muds and loams; so that even in this respect, sawdust is inferior for compost to these materials, which are almost always readily accessible, and to be had as cheaply. From the table on pages 207–245, Vol. I., of this Bulletin, it appears that 100 lbs. of beech-wood, for example, contain only about one-tenth of a pound of real potash, no more than five hundredths of a pound of phosphoric acid, and at the utmost (page 32) no more than a pound of nitrogen, even in wood that has been artificially dried. But as has been shown on page 267, Vol. I., of this Bulletin, peats often contain more than 2% of that element. Of 33 New England peats examined by Professor Johnson, barely one-third of the samples contained less than $1\frac{1}{2}\%$ of nitrogen, and only four of the samples contained less of that element than the poorest of Chevandier's woods (0.81%).

In respect to nitrogen, sawdust is doubtless as good or better than straw, which usually contains no more than one-third of one per cent of nitrogen, but since straw * contains a much larger proportion of potash (0.5 to 1.0%) than wood, and is decidedly richer in phosphoric acid (0.2 to 0.3%) also, and the other essential ash ingredients of plants, it has always been rightly esteemed a much better manure than sawdust. A comparison, such as this, of the constituents of straw with those of sawdust, explains at once why it is that in respect to the quality of the manure obtained, sawdust has been found in practice to be but a poor substitute for straw for bedding animals. It is true that the different absorptive powers of the two materials for the liquid parts of the manure may also have a certain influence on the quality of the final mixture; but it is plain, on the face of the matter, that manure from well-kept stables where sawdust is used for bedding, must necessarily be poorer in inorganic materials than that from similar stables where the manure is mixed with straw.

* See table in Johnson's "How Crops Grow," p. 382.

Curiously enough, the chemical evidence goes to show that it is for feeding animals rather than for feeding plants that sawdust might be put to use. It has, in fact, been shown practically by the experiments of Stœckhardt * and his pupils, that fresh sawdust, even that of pine-trees, can be used with advantage as fodder, in times of dearth, and there is every reason to believe that, poor as it unquestionably is, it could ordinarily be employed in a great variety of cases for maintaining animals, if it were carefully sifted to remove splinters, and used in conjunction with other kinds of foods, in the same sense that straw is now used as a component of many mixtures of fodders.

Twigs and leaves, especially when the latter are young, stand, of course, in a very different category from sawdust. The young and growing parts of plants are, comparatively speaking, rich both in ash ingredients and in nitrogen, and are known to be valuable both for fodder and for manure. From the tables above cited, it appears that 100 pounds of beech-clippings obtained in August, contained, when dry, nearly one pound (0.88) of real potash and a third of a pound of phosphoric acid ; while, as Stœckhardt † has shown, the amount of nitrogen in such twigs and leaves is decidedly high. In a great variety of samples of twigs and leaves from different kinds of trees, Stœckhardt found the proportion of nitrogen in the dried material to range from 1.28 to 2.84%, which is equal to from 8 to $17\frac{3}{4}\%$ of albuminoids ; a result which is not a little striking, in view of the fact that good hay contains on the average no more than 1.6% of nitrogen, or 10% of albuminoids. Twigs and leaves, such as the clippings of vines and hedges, or bushes mown in pastures, are undoubtedly valuable both as forage and as manure. They are manifestly very much better than either straw or sawdust for feeding animals and for making composts. For that matter, the use of browse as cattle food has long been a prominent feature in the husbandry of some southern countries, such as Italy.‡ It was clearly recognized by the early settlers of this country, and is still a resource for the backwoodsman in many districts.

Autumn leaves and the rakings of woodland, which consist for

* In his "Chemische Ackersmann," 1860, **6.** 51; 1861, **7.** pp. 178, 184, and 1869, **15.** pp. 118, 189. Compare "N. E. Farmer," 1832, **11.** 164.

† In his "Chemische Ackersmann," 1860, **12.** 49.

‡ Even Cato, in his De Re Rustica, at the end of chapter v., enjoins upon the farmer to "lop the leafy twigs of poplars, elms, and oaks, and to store them for a time, without too much drying, for sheep fodder."

the most part of leaves that have not only fallen, but have been leached by rains, are, of course, much less valuable than fresh leaves, such as were just mentioned. They may be classed as somewhat inferior to straw. It is to be remembered, in this connection, that when a plant ripens, or makes ready for hibernation, a good part of the valuable constituents of its leaves pass out from the leaves into the fruit or the stem or the root of the plant, there to be stored up for future use. It appears from the table in Volume I. that dead beech-leaves collected in autumn may contain from 0.1 to nearly 0.5% of potash, and from 0.06 to 0.35% of phosphoric acid. Rissmüller (" Versuchs-Stationen," 1874, **17.** 25) found 1.25% of nitrogen in beech-leaves, plucked Nov. 18 and dried at 100°, which is perhaps more than could be fairly expected on the average from leaves that had actually fallen. Stœck-hardt (in his " Feldpredigten," 1856, **2.** 111) puts the amount of nitrogen in fallen beech-leaves at 0.8%.

It should be distinctly understood that there is nothing, in the fore-going statement, which detracts from the merit of tan or sawdust or leached dye-woods, considered merely as materials for mulching. The efficacy of a mulch, viewed as such, depends upon its mechanical texture or condition, and not upon its chemical composition ; and long experience has taught that the substances now in question may often be used, very advantageously, as mulches. Indeed, in many of the accounts that have from time to time been published of the beneficial action of tan composts, or the like, there are plain grounds for suspect-ing that the tan or sawdust really did good service as a mulch, and that the benefit supposed by the experimenters to have been derived from fertilizing ingredients in the tan was really due to another cause. The utility of spent tan as a mulch for fruit-trees has long been known. Many writers have insisted that the tan keeps the ground damp and "loose" and "open," as the terms are, or "in a good state of fermentation," to translate somewhat freely the German term *Gähre ;* and it has been thought by many that fresh tan tends to pre-vent the approach of various insects that might harm the trees or fruit. As Professor Johnson has well said, "Fresh sawdust in light thirsty soils tends to increase the water-holding capacity. In sticky clays it lightens the texture ; and, on soil that forms a hard crust after rain, it prevents, like any other mulch, such puddling and baking of the surface."

The popular notion that crude spent tan is "sour," or that, in other words, it does more harm than good to plants, with which it may happen to come into immediate contact, is doubtless true. As Arthur Young said long ago, "Spent bark seems rather to injure than assist vegetation." But the very facts that spent tan, as it comes from the vats is slightly acid; that it has a slight tendency to destroy plants; and that it decays exceedingly slowly, — enable it to smother weeds and grass all the more effectually, and thus, for many purposes and cases add to its merit as a mulch.

EEL-GRASS.

Although, as has just been said, a substance may serve excellently well as a mulch, even though it contains nothing which can serve as food for plants, it is still true, economically speaking, that in choosing a mulch, other things being equal, those substances would commonly be preferred which do contain some fertilizing ingredients. In this sense, I have sought to compare spent tan and dye-woods, not only with sawdust, as above, but with the common eel-grass (*Zostera marina*) of our sea-coast, a substance that is held in little or no esteem by farmers, either as a fertilizer or as a material for making composts, but which is a good deal used for mulching, as well as for protecting cellars, cisterns, and the like, from frost in winter. A fair sample of dead, dry eel-grass, taken from a beach in Hingham harbor, where it had been deposited by the tide, and kept for some months in a dry loft, on being analyzed by the method described on page 29, was found to contain 14.29% of water, 14.46% of ashes,* 1.0234% of potash, 0.2256% of phosphoric acid, and 1.302% of nitrogen; or, in other words, the ash of the eel-grass contained 7.08% of potash, and 1.56% of phosphoric acid. The experiments of other chemists show that the ashes are rich

* From these data, it appears that the percentage of ash in the eel-grass dried at 110° was 16.87, a result that agrees closely with a determination made by myself, some years since, of the ash in fresh eel-grass. For the experiment in question, a quantity of living eel-grass was pulled up, when the tide was out, from mud flats in Hingham harbor, Sept. 27, 1857, and was examined two days later while it was still wet and perfectly fresh. In two determinations, there was found respectively 85.03% and 86.01% of water, the samples having been dried at 110°. The amount of ash in the wet weed was 2.62%, or in the weed dried at 110°, 17.50%.

A specimen of living rock weed (*Fucus vesiculosus*) collected at the same time and place upon rocks near the shore, contained 76.75 to 77.94% of water, and 3.94% of ash; or 17.88% of ash in the rock-weed dried at 110°.

in lime also, and it is plain that the ashes of eel-grass will compare very favorably as a manure with the ashes of ordinary firewood. See Volume I., page 191.

On contrasting this analysis of eel-grass with the figures previously given, in respect to tan, sawdust, straw, and leaves, it will be seen that not only the ash, but the sea-weed itself is comparatively rich in fertilizing matters, and that it resembles young leaves and twigs gathered in summer more nearly than either of the other materials. The character of the several substances will appear from the following table: —

Per cent of	In eel-grass.	Spent tan.	Straw.	Saw-dust.	Twigs with leaves.
Potash	1.0234	0.08	0.5 to 1.0	0.10	0.88
Phosphoric acid .	0.2256	0.04	0.2 to 0.3	0.05	0.33
Nitrogen . . .	1.3020	0.16	0.33	1.00	1.28 to 2.84

The real difficulty with eel-grass, that has prevented it from being prized as a manure, is its singular power of resisting decay. This peculiarity taken in connection with the physical structure of the plant, makes it obnoxious to the farmer. It is a great hinderance to the labor of moving stable manure or compost, when there is found admixed with these materials any thing that, like eel-grass or leather, is continually clogging the forks. It is difficult, moreover, to spread evenly manure which is thus contaminated, or to secure the clean tillage of land that has been dressed with it. It is on this account that eel-grass is little esteemed as litter, and that no thoroughly satisfactory method of using it as a fertilizer has yet been devised.

No. 4. — *On the Composition of Buckwheat Straw.* By
F. H. STORER, Professor of Agricultural Chemistry.

FROM several of the published tables of the average composition of
the ashes of plants,[*] it would appear that the proportion of phosphoric
acid in the ashes of buckwheat straw is very much higher than it is
in the ash of other kinds of straws. At first sight, it would seem as
if this difference might be due to the dissimilarity of the buckwheat
plant to the other plants whose straws are enumerated in the tables.
The close botanical relations of buckwheat with various plants that
are commonly classed as weeds, and the fact that the ashes of many
weeds contain a good deal of phosphoric acid, tend to support this
idea. But the force of the argument is greatly diminished by the
facts that the straws of pea, bean, rape, and poppy plants, as well as
those of the cereals, are included in the tables, and that no one of these
straws yields ashes that contain nearly as much phosphoric acid as has
been allotted to the ash of buckwheat straw. Moreover, the analyses
that have indicated the presence of large amounts of phosphoric acid
in the ashes of weeds were analyses of the ashes of entire plants;
that is to say, of the ash of leaves, stems, flowers, and often seeds,
that had been burnt all together: they do not refer to the ashes of mere
straw, and they have consequently no very immediate bearing upon the
present inquiry.

In seeking for an answer to a student's question, as to the meaning
of the current statement that buckwheat straw is so exceptionally
rich in phosphates, I noticed that the figures given in the tables just
referred to, depend solely upon six analyses of buckwheat stalks (free
from leaves), of exceptional character, that were made by Wolff,[†] in
connection with some experiments of his on the influence of inorganic
fertilizers upon the growth of plants. These analyses, though evidently
excellent in themselves, are plainly unfit to give the average composi-
tion of buckwheat straw, or to justify a belief that such straw is
ordinarily highly charged with phosphates. In order to obtain some

[*] See, for example, the tables in Johnson's "How Crops Grow." New York,
1868, pp. 158, 378.

[†] "Journal für praktische Chemie," 1850. 51. 38; and 1851, 52. 102.

new evidence upon this point, I have had the amounts of phosphoric acid and of potash very carefully estimated in a couple of samples of buckwheat straw, such as farmers have to do with. The samples were taken early in May, 1876, from barns on two separate farms at Wethersfield, Connecticut, by my friend Mr. Charles Wright, the well-known botanist. The straw had been threshed some time previously, in both cases. Sample No. II. was taken from a heap or mow of the straw that had been kept in the barn to be used for bedding cattle, and was in excellent condition. No. I., on the other hand, was a not particularly good specimen, since in this instance the main body of the buckwheat straw had been thrown out from the barn at the time of threshing, and the sample had to be obtained by picking out special stalks, one by one, from a quantity of hay that had become somewhat mixed with the buckwheat straw after the threshing. This sample, like the other, consisted entirely of buckwheat straw, only the straw was not in such good condition in sample No. I. as in No. II. Both samples had naturally been pretty thoroughly deprived of leaves during the process of threshing. The proportion of small branches and flower-stalks to the large stems or buts was rather smaller in No. I. than in No. II.

The phosphoric acid and the potash were not estimated in the ashes of the straw, but in the straw itself; that is to say, in solutions obtained by decomposing known weights of the straw with nitric acid, as has been explained on page 29 of this Bulletin. The purpose of this mode of treatment is to avoid the risk of losing any phosphoric acid or potash by way of volatilization in the process of burning the plant. Compare Volume I., page 199.

The percentage of total ash was determined by burning some of the straw in a platinum dish in the usual way, and from the amount of ash thus obtained, and the amounts of phosphoric acid and potash found in the straw, the proportions of these substances in the ashes were calculated.

The following results were obtained on analyzing the straws : —

Buckwheat Straw : —	I.	II.	Mean of the two analyses.
Moisture expelled at 110° . . .	10.35%	10.39%	10.37%
Crude ash	6.55	5.86	6.21
Ash, free from C and CO_2 . . .	4.94	5.16	5.05
Phosphoric acid in the straw . .	0.21	0.41	0.31
Potash in the straw	1.72	2.50	2.11

Percentage of —

Phosphoric acid in the crude ash .	8.17	6.95	5.06
Potash in the crude ash	26.21	42.62	34.41
Phosphoric acid in the ash free from C and CO_2	4.20	7.89	6.04
Potash in the ash free from C and CO_2	34.75	48.40	41.57

In other words, a ton (2000 lbs.) of the straw would contain about 6¼ lbs. of phosphoric acid, 40 or 50 lbs. of real potash, and 12 lbs. of nitrogen, as will be shown directly.

The analyses of Malaguti and Durocher,[*] of stalks and leaves of buckwheat plants gathered at the end of September in Thorigne, France (III.); of Moser,[†] of buckwheat plants that had been mown for fodder, September 25, when in full blossom (IV.); and of Vauquelin [‡](V.), — all go to show, like the analyses given above, that buckwheat straw is by no means so exceptionally rich in phosphates as would appear from the analyses of Wolff. [§] Thus, there was found by —

	III Malaguti & Durocher. In pure ash, i.e. ash free from C & CO_2.	IV. Moser.	V. Vauquelin. In crude ash, containing besides CO_2, 16¼% of silica and sand.
Potash	30.64% [‖]	24.61%	More than 16 10% [¶]
Phosphoric acid . .	7.70	6.11	4.81
Salts soluble in water .	36.44	——	38.33

The average amounts of potash and phosphoric acid contained in the ashes (free from C and CO_2) of other kinds of straws, are given by Johnson ("How Crops Grow," p. 153), as follows: —

	Wheat Straw.	Rye Straw.	Barley Straw.	Oat Straw.	Pea Straw.	Bean Straw.
Potash	11.5	15.4	21.6	20.5	21.4	32.7
Phosphoric acid .	5.3	5.3	4.5	4.1	7.1	7.9

The fact that the proportion of potash in the buckwheat plant is large was insisted upon long ago by Vauquelin,[**] who urged that the

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[*] "Annales de Chimie et de Physique" 1858, **54.** 257 and table B.
[†] Wolff's "Aschen-Analysen," Berlin, 1871, p. 41.
[‡] "Journal des Mines," 1801-2, **11.** 525.
[§] See Johnson's "How Crops Grow," page 163.
[‖] Potash and soda together.
[¶] Obtained from the soluble part of the ashes, only.
[**] "Journal des Mines," 1801-2, **11.** 525.

ash of the buckwheat gave him nearly 30% of carbonate of potash, while the ashes of most other plants yield only some 18 or 20%.

FODDER VALUE OF BUCKWHEAT STRAW.

While the specimens of straw above described were in hand, it seemed desirable to determine by analysis what proportion of substances useful for feeding animals were contained in the samples; or, rather, to contrast the proximate composition of the buckwheat straw with that of other straws, and with the various refuse matters that are used as litter. So far as I am aware, no such analysis has ever been made, except a single nitrogen determination, by Boussingault and Payen,[*] who found in a straw that contained 11.6% of water, 0.48% of nitrogen, or 0.54% of nitrogen in dried straw. That is to say, 3% of albuminoids in the air-dried straw, and 3.38% in the anhydrous straw.

From the analysis of my own samples, it appeared that there was contained in —

	No. I.	II.	Mean of the two analyses.
Water	10.35	10.39	10.37
Ash free from C & CO_2 . . .	4.94	5.16	5.05
Albuminoids	4.38	3.33	3.85
Carbohydrates, including fat . .	33.50	36.19	34.85
Cellulose, free from ash . . .	46.83	44.93	45.88
	100.00	100.00	100.00
Dry organic matter	84.71	84.45	84.58
Fat (ether extract)	1.42	1.70	1.56
Nitrogen	0.698—0.706	0.532—0.532	0.617
Crude ash	6.55	5.86[†]	6.21

These figures are very like those which have been obtained by the analysis of the straw of barley and of the other ordinary grains, as will be seen on comparing them with the table on page 353 of the first volume of this Bulletin; or, better, from the table given below, from which all variations due to the presence of moisture have been excluded, by taking for the comparison the average composition of straws that have been dried at 110°.

[*] "Annales de Chimie et de Physique," 1841, 3. 100.
[†] In another trial, 5.95 %.

COMPOSITION OF THE DRY MATTER IN STRAWS.*

Kind of Straw.	Albuminoids.	Carbohydrates, including Fat.	Fat.	Cellulose.	Ash (free from C & CO_2).	The proportion of dry matter (including ash) in the ordinary air-dried material is:
Wheat	3 50	48.63	1 27	43.32	4.55	86.45
Rye	4.15	39 94	1.55	51.34	4 56	87.00
Oat	5.26	44 73	1.89	43.93	6 08	86.39
Barley	4 11	39.23	2.19	48.42	8 24	86.69
Pea	8.81	36.67	2.54	49 51	4 81	85.72
Bean	14.60	40.34	1.59	37 29	7.77	82.18
Buckwheat (mean of the analyses given above)	4.30	38.68	1.74	51.19	5.63	89.63
Buckwheat plants mown green for fodder*	14.49	45.86	4.66	30.89	8.76	14.14

It would seem, from the analyses, that buckwheat straw, when mixed in small proportion with richer kinds of foods, might, like other straws, be usefully employed for feeding animals in many cases; especially if it were previously softened by steaming or soaking. A certain prejudice against the use of this straw as fodder, which undoubtedly prevails in many localities, evidently depends upon a tradition that has come down to us from much earlier times, to the effect that the buckwheat plant is liable to do positive harm to animals that feed upon it. Linnæus,† in the report of one of his botanical journeys, mentions the belief of the Swedish peasantry that when sheep eat buckwheat straw they are made sick by it. Cows, they said, ate the straw with impunity, but horses would not eat it. Several of the earlier German writers on agriculture mention the belief that prevailed in their country that the buckwheat plant is dangerous food for animals. These views, though often cited now-a-days, have repeatedly been combated, and to all appearance have been refuted for the most part. The distinguished south-German agri-culturalist Schwerz,‡ for example, did not share the fears of his predecessors and contemporaries, and was at pains long ago to adduce evidence that mown buckwheat is excellent food for all kinds of grass-eating animals. Nor do the old statements consist with the views of various modern writers, who recommend green-cut buckwheat with very little

* Copied with some slight alterations from Dietrich & Kœnig's " Zusammensetzung der Futterstoffe," Berlin, 1874, pp. 76, 77.

† " Natur- Kunst- und Œconomie Historie von einigen schwedischen Provinzien," Leipzig, 1756, p. 105.

‡ " Culture des plantes Fourragères," Paris, 1842, p. 188.

reserve as an excellent fodder, liable to produce diarrhœa indeed when given in too large proportion, and to cause a kind of intoxication in sheep and swine who have been allowed free access to the plants, but harmless when mixed with other less succulent food, and fed out with care and judgment. To all appearance, the controversy teaches merely that special care should be exercised in using the buckwheat plant as fodder, particularly as regards sheep and swine. Neither the green plant nor the straw should be fed out except in admixture with other kinds of foods, and animals should never be permitted to have free access to the plant in the field.

Sprengel, * who held with the earlier writers that the buckwheat plant must contain some peculiar substance hurtful to animals, expressed their views and his own in the following terms : " Swine that have eaten freely of green buckwheat plants, and have then been exposed to the hot sun, often fall down in violent convulsions." . . . " Dry buckwheat straw, moreover, does not agree specially well with neat cattle. It has often been noticed, in districts where buckwheat is largely grown, that cows are liable to cast their calves prematurely, after eating abundantly of this material.   It is preferred to feed out buckwheat straw to oxen and young stock in early winter, since it does not agree with them later in the season."

According to v. Gohren, † the bad effects which have occasionally been observed to be produced upon animals that have eaten buckwheat are confined almost exclusively to sheep and swine, and to individuals that are either white or mottled with white. He insists that animals with dark-colored hair have never been known to suffer from eating buckwheat. Sprengel, on the contrary, perhaps by mistake, says that the illness, as above cited, is specially liable to occur with animals that are black.

It would be interesting to study this question carefully, and to determine what the hurtful constituent is, if there be any, but it is to be noticed meanwhile that a good part, if not the whole, of the inconveniences attributed by Sprengel to the use of buckwheat straw may have been caused by the injudicious or too exclusive use of it. The mere mechanical texture of the straw would of itself indicate that cattle should not be forced to eat too large a proportion of it.

In his book entitled " Instruction in Farming and Stock-raising," which has long been recognized in Germany as a standard work on these subjects, Koppe ‡ sums up the question as follows: —

" The most contradictory views are held as to the fodder value of buckwheat straw. Some farmers esteem it to be equal to hay, while others deny that it has any value as fodder, while others still apprehend that

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* " Erdmann's Journal für tech. und œk. Chemie," 1829, **5.** 145.

† In his " Naturgesetze der Futterung," Leipzig, 1872, p. 196.

‡ " Unterricht im Ackerbau und Viehzucht," 10te Edition. Edited by **Prof. Wolff,** Berlin, 1873, p. 519.

actual harm would be done the animals to which it might be fed. These differences of opinion are all the more remarkable, in view of the facts that buckwheat has long been cultivated, and that very large amounts of it are grown in some localities. It may perhaps seem still more extraordinary to the reader that I am myself obliged to confess that an experience of fifty years has not been sufficient to clear up these contradictions in a manner satisfactory to myself. Several facts have been communicated to me by trustworthy persons, which certainly go to show that under certain circumstances the pasturing of buckwheat stubble and the eating of buckwheat straw and chaff occasion unusual appearances. It is said, for example, that the heads of sheep swell up, and that swine become benumbed. Such appearances have, however, always been transitory, and it has not been perceived that the animals ever suffered any permanent injury. I have myself, on the contrary, in many years, harvested more than 2000 bushels of buckwheat grain on single farms, and have never experienced any thing but the greatest advantage on feeding out the straw and chaff to sheep and neat cattle. In seasons when the weather had been specially favorable for harvesting the straw, my sheep, although not actually forced by hunger to do so, have eaten up the buckwheat straw as clean as if it had been hay, leaving scarcely a single stalk of it uneaten. In the course of this long-continued and wholesale use of the buckwheat straw, I have never seen with my own eyes any of the injurious effects that have been ascribed to it, and I am consequently inclined to believe that the locality in which the straw is grown must have a very important influence in producing these effects."

It is to be observed that in the old tables of Hay-worths, which were supposed to give the value of each kind of fodder, as determined by farm experience, in comparison with that of good hay, buckwheat straw was often classed with barley straw, as being worth about half as much as hay.

No. 5. — *On the Fertilizing Power of Roasted Leather.* By
F. H. STORER, Professor of Agricultural Chemistry.

IT is a familiar fact of agricultural experience that ordinary leather
is of no use as a fertilizer, excepting in so far as it may sometimes be
employed for mulching. The fact is one that has specially attracted
the attention of chemists, since it goes to show not only that the five
or six per cent of nitrogen contained in leather is useless for feeding
plants, but that plants need to have their nitrogenous food presented
to them in fit forms, and that, furthermore, the nitrogen in leather must
be held in some very peculiar state of chemical combination.

As is well known, a good part of this inert nitrogen can be recovered
for use as a fertilizer, by subjecting leather to destructive distillation,
and collecting the ammoniacal distillate, either in an acid, or in mere
earth, in case the product is to be used in the immediate vicinity of the
place where it is prepared.   The process recently devised by L'Hôte [*]
for distilling leather scrap and the like with soda lime, as an economi-
cal method for the manufacture of ammonium salts, may perhaps turn
out to be of considerable importance from the agricultural point of
view.   But, aside from actual distillation, it has been suggested at one
time and another that the inert nitrogen compound in leather could be
broken up and the nitrogen in it made available for plants, by merely
heating or " roasting " the leather, at temperatures considerably lower
than that at which destructive distillation occurs.

In order to determine whether roasted leather has any fertilizing
value, I have subjected some of it to the test of practical trial, by
growing a number of buckwheat plants in jars of earth and of sand,
each of which contained a definite quantity of the leather, and which
were moreover supplied, in addition to the leather, with one or more
of the several kinds of food that are known to be necessary for the
growth of plants.   The intention was so to arrange the experiments
that the fertilizing power of the leather, if any there were, should
have an opportunity to exhibit itself in some one or more of the jars;
that is to say, in those jars whose soils had been purposely deprived
of that special kind of plant-food which the roasted leather might be
competent to supply.   For purposes of comparison, experiments upon

several other substances, viz., upon simple unroasted sole leather, and sheepskin, upon cotton cloth, sponge, and anthracite, both natural and roasted, and upon simple sand or earth to which no leather or the like had been added, were tried at the same time with those upon the roasted leather.

The experiments were all made in wide-mouthed glass jars (preserve jars), in the glass-house or conservatory which forms a part of the Bussey Laboratory, and were conducted in the same general way as the experiments previously described in this Bulletin, Volume I. pages 54 and 253. In the first set of experiments, the leather or other material was mixed with Berkshire sand.* Ten sets of jars, each set consisting of seven pieces, were charged as follows: —

A. With 1300 grammes Berkshire sand and 20 grms. of the shavings of sheepskins. These shavings came from the flesh side of skins that had been tanned in sumac. They were in the air-dried state when taken for these experiments. The shavings were cut into fine shreds before being put into the jars. The jars were charged with alternate layers of the shreds and the sand. It may here be remarked that the very bulky character of the sheepskin and of several of the other materials interfered somewhat with the conduct of the experiments. With such voluminous materials, it is difficult to charge each jar precisely like the others of its set, and in watering the plants, afterwards, special care has to be exercised in order that all the jars may be kept properly moist.

B. With 1300 grms. Berkshire sand and 20 grms. of roasted sheepskin. The product here in question was obtained by heating shreds of sheepskin to 160° @ 180° (C.) in a tin cup sunk in sand at the bottom of an iron pot. A thermometer was kept in the cup, and the sheepskin was stirred continually until the whole of it had become brown and friable. The roasted product was ground to powder in a mortar, and the weighed quantity destined to each jar was thoroughly mixed upon a plate, with the 1300 grms. of sand, before putting the mixture in the jar.

C. With 1300 grms. Berkshire sand and 40 grms. sole leather. The leather was new and clean. It was cut into fragments as large as small peas, and mixed with the sand in the jars, layer by layer.

D. With 1300 grms. Berkshire sand and 40 grms. roasted sole leather. A quantity of small cubes of the leather, such as were mentioned above, under C., were roasted at temperatures ranging from 180° to 200° (C.) or more, in a tin cup sunk in sand as explained in paragraph B., or until the whole of the leather was black and brittle, and a good many of the pieces had become puffed out and swollen, like parched corn.

It was found to be much less easy to regulate the temperature of the roasting of sole leather than of sheepskin. In order to obtain the peculiar swollen or parched effect just mentioned, the temperature of the sand bath had to be raised so high that it was less easy to control it than was the case at lower temperatures, so that some bits of the leather were

* Compare Bussey Bulletin, 1. 59, and 2. pp. 11, 17.

more strongly heated than others. A roasted material, thus obtained, may of course represent a variety of products, corresponding to the several temperatures at which they were produced; but on some accounts such complexity would be advantageous for experiments like those now in question, since, if any one among the various products were useful as plant food, the fact would be exhibited by the crops, and the chances of finding such an one would probably increase with the number of the products.

As was the case with the roasted sheepskin, the whole of the roasted leather obtained was ground together to a fine homogeneous powder, from which separate quantities, sufficient for each jar, were weighed out, to be mixed with the corresponding quantities of sand.

E. With 1300 grms. Berkshire sand and 18 grms. fine clippings of worn and washed, thin cotton cloth. The shreds of cloth were mixed with the sand by alternate layers. Besides the chemicals enumerated in the tables, this set of jars, excepting Nos. 4 and 5, were watered once at the beginning of the experiments with a solution of sulphate of lime.

F. With Berkshire sand alone. These jars, like the foregoing set, were watered once with sulphate of lime.

G. With 1200 grms. Berkshire sand and 7 grms. chopped Nassau sponge. The sponge was washed with chlorhydric acid and with water, dried and cut into small pieces, which were mixed with the sand in the jars, by alternate layers.

H. With 1000 grms. of powdered anthracite. It may here be said that one purpose of experiments H, I, and J, was to ascertain, if possible, the source of a certain small amount of assimilable nitrogen that had been previously noticed in the ashes of anthracite.* The true explanation of this question was discovered afterwards, as has been explained on page 401.

I. With 1100 grms. Berkshire sand and 180 grms. anthracite powder.

J. With 1100 grms. Berkshire sand and 180 grms. roasted anthracite; *i.e.*, powdered anthracite that had been heated to 250° (C.) in a tin cup sunk in sand. When thus heated, the anthracite gave off a small amount of moisture; but there was no evidence of any change that could have unlocked any of the nitrogen in the coal, or have increased the assimilability of any of its constituents.

The foregoing experiments were made in the autumn of 1874, three buckwheat seeds having been planted in each jar on the 14th of November. The seeds were watered with rain-water at first; but, after the plants appeared, each jar was watered with the solution of some one special chemical substance, as stated in the tables below. The solutions of these chemicals were made with rain-water, and were of the following strengths: Sulphate and phosphate of potash, 0.25 grm. to the litre; nitrate of lime, 1 grm., and nitrate of potash 1.25 grms., to the litre. In the present series of experiments, there were two more jars in each set than in the other series. For jars Nos. 5 and 6 of the present series, the two kinds

* See Bussey Bulletin, 1. 62.

of chemicals employed were used alternately, — the one upon one day, and the other upon the next, — a method which was afterwards discarded as being inferior to the method of using every day for these jars (or for jar No. 5) a mixture composed of equal volumes of the solutions of the two chemicals.

A second set of experiments, made in the spring of 1876, was analogous to the foregoing (A. to F.), in that the jars contained the same kinds and quantities of leather or cotton; but, instead of mere sand, each jar contained a mixture of 760 grms. Berkshire sand and 560 grms. of calcined loam; *i.e.*, garden earth of fair quality that had been calcined at low redness in a muffle, to destroy all organic matter.

In a third series of experiments, sand from a dune at Provincetown, Mass., was employed in place of the Berkshire sand of the first series, the idea being to get a soil of different texture from the soils of the other series. In this series of experiments, as with the second series, three buckwheat seeds were planted in each jar, January 17, 1876. The results of all these trials are given in the following tables. Each of the crops was dried at 90° to 100° C., before weighing : —

No. of jar.	The jar was watered with —	Each jar contained 20 grms. *Sheepskin* and 1300 grms. Berkshire sand.			Each jar contained 20 grms. roasted *Sheepskin* and 1300 grms Berkshire sand.		
		The crop harvested Feb. 3, 1875.			The crop harvested Feb. 3, 1875.		
		Weig'd grms.	Grew to height	Had seeds	Weig'd grms.	Grew to height.	Had seeds.
0	Sulphate of potash .	0.130	2″ 4″ 4½″	0	0.190	6″ 6″ 6½″	4 (sm'l)
1	Phosphate of potash .	0.055	1 3 3½	0	0.060	2 2 3½	0
2	Rain-water . . .	0.100	2½ 3 3½	0	0.105	2 3 3	0
3	Nitrate of potash . .	0.215	6 6 6½	2	0.190	5 6½ 7	1
4	Nitrate of lime . . .	0.160	3 3 4	0	0.125	3½ 4 4½	0
5	Phosphate of potash and nitrate of lime .	0.640*	5 6 8	0	0.250	?† 4½ 5½	0
6	Phosphate of potash and nitrate of potash	0.530*	12 13 13	8	0.080	?† ? 4	0

* Not yet ripe when harvested.
† Several of the plants in these jars wilted and died a month after the seeds were sown. The others were green and unripe when harvested.

No. of jar.	The jar was watered with —	Each jar contained 20 grms *Sheepskin*, 760 grms. Berkshire sand, and 560 grms. calcined loam.			Each jar contained 20 grms. roasted *Sheepskin*, 760 Berk. sand, and 560 calc. loam.		
		The crop harvested April 3, 1876.			The crop harvested April 3, 1876.		
		Weig'd grms.	Grew to height	Had seeds.	Weig'd grms.	Grew to height.	Had seeds.
1	Phosphate of potash .	0.120	3″ 3½″ 4½″	0	0.700	3½″ 5″ 5½″	4
2	Rain-water	0.170	4½ 5 5½	1	0.850	5½ 5½ 6	4
3	Nitrate of potash . .	1.720	9½ 10 12½	8	1.950	5½ 6 7	7
4	Nitrate of lime . . .	1.520	7 9 9½	14	3.170	6 6 8½	27
5	Phosphate of potash and nitrate of lime .	4.020	9 9½ 14½	33	3.000	8 10 10	30

No. of jar.	The jar was watered with —	Each jar contained 20 grms. *Sheepskin* and 1450 grms. Provincetown sand.			Each jar contained 20 grms. *roasted Sheepskin* and 1450 Provincetown sand.		
		The crop harvested April 3, 1876.			The crop harvested April 3, 1876.		
		Weig'd grms.	Grew to height.	Had seeds.	Weig'd grms.	Grew to height.	Had seeds.
1	Phosphate of potash .	0.100	3½″ 3½″ 3½″	0	0 470*	4″ 4½″ 5″	1
2	Rain-water	0.080	2½ 2½ 3½	0	0.250*	3½ 4 5½	0
3	Nitrate of potash . .	0 500	6½ 7 9	0	0 275	5 5 6	½
4	Nitrate of lime . . .	0.480	2½ 2½ 3	0	0.250	2 3½ 3½	0
5	Phosphate of potash and nitrate of lime	1.400	7½ 9½ 15	6	0 345*	4 4 5	1

* Green and immature, when harvested.

No. of jar.	The jar was watered with —	Each jar contained 40 grms. *Sole Leather* and 1300 grms. Berkshire sand.			Each jar contained 40 grms. *roasted Sole Leather* and 1300 grms. Berks. sand.		
		The crop harvested Feb. 2, 1875.			The crop harvested Feb. 3, 1875.		
		Weig'd grms.	Grew to height.	Had seeds.	Weig'd grms.	Grew to height.	Had seeds.
0	Sulphate of potash .	0.115	2½″ 3″ 4″	0	0 230	2½″ 4½″ 6″	0
1	Phosphate of potash .	0.120	3½ 3½ 4½	0	0.210*	4 5 6	0
2	Rain-water	0 110	2 2 3	0	0 220*	3½ 4 5½	0
3	Nitrate of potash . .	0.230	4 4 6	0	0.295	4 6 8	0
4	Nitrate of lime . . .	0 155	Small.	0	0.290*	4 5 5	1
5	Phosphate of potash and nitrate of lime .	0.280	3½ 3½ 3½	0	0.360*	3½ 5½ 7	0
6	Phosphate of potash and nitrate of potash	0.385	4 7 9½	1	0.345*	5 5 6	0

* Green and immature, when harvested.

No. of jar.	The jar was watered with —	Each jar contained 40 grms. *Sole Leather*, 760 grms. Berkshire sand, and 560 grms. calcined loam.			Each jar contained 40 grms. *roasted Sole Leather*, 760 B sand, and 560 calc. loam.		
		The crop harvested April 3, 1876.			The crop harvested April 3, 1876.		
		Weig'd grms.	Grew to height.	Had seeds.	Weig'd grms.	Grew to height.	Had seeds.
1	Phosphate of potash .	0.150	3½″ 4″ 4½″	0	1.980	8½″ 9½″ 11″	19
2	Rain-water	0.130	2½ 3½ 4	1	2.120	6 7½ 8½	22
3	Nitrate of potash . .	1.810	10 11 11	4	2.510	5 8½ 9½	15
4	Nitrate of lime . . .	2 315	6½ 7 8	3	2.400	5 6½ 7½	17
5	Phosphate of potash and nitrate of lime .	3.720	9½ 11 14½	30	4.785	6½ 9 10½	21

Each jar contained 18 grms. Cotton Cloth and 1300 grms. Berkshire sand. — The crop harvested Feb. 4, 1875.

No. of jar	The jar was watered with —	Weighed grammes.	Grew to height.	Had seeds.
0	Sulphate of potash	0.130	2½″ 3″ 3″	0
1	Phosphate of potash	0.095	2¼ 3¼ 3¼	0
2	Rain-water	0.160	3 4 4	1
3	Nitrate of potash	0.295	5 5 6	0
4	Nitrate of lime	0.310	3½ 3½ 4½	0
5	Phosphate of potash and nitrate of lime	0.765	9 9 11	3*
6	Phosphate of potash and nitrate of potash	0.750	10 10 11	0*

* And several flowers.

Each jar contained 18 grms. Cotton Cloth, 760 Berkshire sand, and 560 calcined loam. — The crop harvested April 3, 1876.

No. of jar	Weighed grammes.	Grew to height.	Had seeds.
0			
1			
2	0.180	3½″ 4½″ 4½″	0
3	0.180	3½ 4 4	0
4	1.670	6½ 9 9	2
5	1.625	6 7 7½	14
6	2.720	10½ 11 11½	18

Each jar contained 18 grms. Cotton Cloth and 1460 grms. Provincetown sand. — The crop harvested April 3, 1876.

No. of jar	Weighed grammes.	Grew to height.	Had seeds.
0			
1			
2	0.085	2″ 2½″ 3″	0
3	0.120	2 3 4	0
4	0.500	6½ 6½ 7	3
5	0.550	3 4 4	0
6	1.150	6 6½ 11¼	7

Each jar contained 1360 grms. Berkshire sand, alone. — The crop harvested Feb. 4, 1875.

No. of jar	The jar was watered with —	Weighed grammes.	Grew to height.	Had seeds.
0	Sulphate of potash	0.200	3″ 4″ 5″	0
1	Phosphate of potash	0.155	3 4 5	2
2	Rain-water	0.200	3½ 4 5¼	3
3	Nitrate of potash	0.335	6 7 7½	2
4	Nitrate of lime	0.380*	5 5½ 8	2
5	Phosphate of potash and nitrate of lime	0.605*	4 8 8	0
6	Phosphate of potash and nitrate of potash	0.670*	8 9 9	1

Each jar contained 760 Berkshire sand and 560 calcined loam. — The crop harvested April 3, 1876.

No. of jar	Weighed grammes.	Grew to height.	Had seeds.
0			
1			
2	0.160	4″ 5″ 5½″	2
3	0.270	5 5 9	0
4	3.820	6½ 8½ 10	40
5	4.810	7 10 16½	55
6	5.830	13½ 16 16½	51

Each jar contained 1460 grms. Provincetown sand, alone. — The crop harvested April 3, 1876.

No. of jar	Weighed grammes.	Grew to height.	Had seeds.
0			
1			
2	0.165	4″ 4½″ 5½″	0
3	0.170	4 4 9	1
4	0.920	7½ 5 9	7
5	0.750	4½ 5 5½	3
6	3.050	7 8½ 10	46

* Plants not yet ripe, when harvested.

No. of jar	Each jar contained 40 grms. *Sole Leather* and 1450 grms. Provincetown sand.				Each jar contained 38 grms. *roasted Sole Leather* and 1450 grms. Province. sand.			
	The jar was watered with —	Weig'd grms.	Grew to height.	Had seeds.	Weig'd grms.	Grew to height.	Had seeds.	
1	Phosphate of potash .	0.110	2½″ 4″ 5″	0	1.750	6½″ 8″ 11″	13	
2	Rain-water	0.120	1½ 2½ 4	0	0.910	3½ 5 6½	4	
3	Nitrate of potash . .	0 460	5½ 6 7	6	0.900	4½ 7½ 9	{1 and fl w'rs	
4	Nitrate of lime . . .	0.820	4 6½ 7	7	1.870	5½ 6½ 7½	14	
5	Phosphate of potash and nitrate of lime .	2.820	10 10½ 11	31	3.120	8 9½ 10½	8	

No. of jar	Each jar contained 7 grms. *Sponge* and 1200 grms. Berkshire sand.			
	The crop harvested Feb. 4, 1875.			
	The jar was watered with —	Weighed grammes.	Grew to height.	Had seeds.
0	Sulphate of potash	0.290	4″ 4½″ 4½″	0
1	Phosphate of potash	0.270	4 5 5½	0
2	Rain-water	0.200	4 4 4½	0
3	Nitrate of potash	0.240	4 6½ 7½	2
4	Nitrate of lime	0.260	2½ 3½ 3½	0
5	Phosphate of potash and nitrate of lime	0.905	4 7 8	4
6	Phosphate of potash and nitrate of potash	0.555	9 10 12	2

No. of jar	Each jar contained 1000 grms. *Anthracite Powder*, alone.			
	The crop harvested Feb. 2, 1875.			
	The jar was watered with —	Weighed grammes.	Grew to height.	Had seeds.
0	Sulphate of potash	0.150	2½″ 5½″ 7″	3
1	Phosphate of potash	0.290	7½ 10 11	8
2	Rain-water	0.185	5 6 7½	1
3	Nitrate of potash	0.280	6 7½ 8	2
4	Nitrate of lime	0.380	6 6½ 7	0
5	Phosphate of potash and nitrate of lime	0.720	6½ 9½ 11½	1
6	Phosphate of potash and nitrate of potash	0.260	4½ 5½ 8½	1

No. of Jar.	The jar was watered with —	Each jar contained 180 grms. *Anthracite Powder* and 1100 grms. Berkshire sand.			Each jar contained 180 grms. *roasted Anthracite* and 1100 grms. Berks sand.		
		The crop harvested Feb 3, 1875.			The crop harvested Feb. 3, 1875.		
		Weig'd grms.	Grew to height	Had seeds	Weig'd grms.	Grew to height.	Had seeds.
0	Sulphate of potash	0.195	3″ 5″ 5½″	0	0.140	2″ 5″ 5″	0
1	Phosphate of potash	0.180	3½ 5½ 5½	1	0.140	3½ 5½ 6	1
2	Rain-water	0.125	2½ 3 4	0	0.180	4 5 5¾	1
3	Nitrate of potash	0.180	6 6 7	1	0.230	5 6 9	0
4	Nitrate of lime	0.330	5 6 7	0	0.250	3 3½ 6	3
5	Phosphate of potash and nitrate of lime	0.845	5 7 8	1	1.030	7½ 9½ 11	7
6	Phosphate of potash and nitrate of potash	0.470	9 10 10	5	0.510	11 11 12	2

It will be seen plainly enough, on inspecting these tables, that while neither the cotton cloth, the sheepskin, nor the sole leather supplied any nitrogenous food to the buckwheat plants, some nitrogen was unquestionably obtained by the plants from the roasted leathers; a very little, namely, from the roasted sheepskin, and a decidedly larger amount from the roasted sole leather. Thus while jars Nos. 0, 1, and 2, which received no intentional supply of nitrogenous food, yielded crops whose weights ranged from less than 0.1 grm. to no more (with a single exception) than 0.2 grm., in the case of sands alone, and of sands or loam with which cotton, sheepskin, or sole leather had been mixed, the corresponding jars that contained roasted sole leather yielded crops that weighed ten times these quantities, in several instances. With roasted sheepskin, the gain, though less decided, is still evident, as will be seen from the following table, excepting one set of experiments in which the roasted product was mixed with Berkshire sand. The mean weight of the crops obtained from 28 of the jars, Nos. 0, 1, and 2, just now alluded to, that contained mere sand, or sand and loam admixed with cotton, or the air-dried leathers, was only 0.139 grm.; while the weights of the crops obtained in similar jars, by the use of the roasted leathers, were respectively as follows: —

No. of Jar.		ROAST SHEEPSKIN, *together with*			ROAST SOLE LEATHER, *together with*		
		Berks. Sand,	Loam,	Prov. Sand.	Berks. Sand,	Loam,	Prov. Sand.
0	(Sulph. potash)	0.190	——	——	0.230	——	——
1	(Phosp. potash)	0.060	0.700	0.470	0.210	1.980	1.750
2	(Rain-water)	0.105	0.850	0.250	0.220	2.120	0.910

The crops obtained from the unroasted leathers weighed:

		SHEEPSKIN.			SOLE LEATHER.		
0	(Sulph. potash)	0.130	——	——	0.115	——	——
1	(Phosp. potash)	0.055	0.120	0.100	0.120	0.150	0.110
2	(Rain-water)	0.100	0.170	0.080	0.110	0.130	0.120

That is to say, they were rather worse than the crops grown in mere
sand. Corroborative evidence that the roasted products can supply
some nitrogen to plants is to be found in the results obtained in jars
Nos. 3 and 4, to which nitrogenous foods were purposely added, and
in those from the jars numbered 5, which received a well-nigh com-
plete mixture of foods.   By comparing one with another the weights
of the crops obtained in these jars, it will be seen that the results
obtained with the roasted leathers are perfectly consistent with the
conclusions just now announced.

In all cases, the light, bulky materials, whether cotton, leather, or
roasted leather, tended to interfere with the growth of the plants;
evidently because the mechanical condition of the sands or loam with
which these substances were mixed was inferior to that of the sands
or loam to which no organic matter had been added.   Better crops
were obtained, for example, in jars Nos. 3, 4, and 5, that were charged
with nothing but a mixture of sand and calcined loam, than in any of
the other jars; but the roasted leathers did better, on the whole, in
jars thus numbered, than the cotton or the simple leathers, both in the
case of the calcined loam, and in that of the Provincetown sand.   In
the poor Berkshire sand, the influence of nitrogenous food is naturally
very slight, no matter whether it be offered in the form of roasted
leather, or in that of nitrate of potash or nitrate of lime, because in
such sand the other kinds of plant food (potassic and phosphatic) are
lacking.   But even here, as well as in the other series of experiments,
the marked leafiness and greenness of the crops in jars Nos. 3, 4, 5,
and 6, went to show how much more efficient the nitrates were, as
sources of nitrogen, than any of the materials that were supplied to
jars Nos. 0, 1, and 2.   It should be observed, in this connection, that
the crops obtained from jars Nos. 5 and 6, in the Berkshire sand series
of experiments, were smaller than I have usually obtained hitherto
from such sand when supplied with the stated kinds of chemicals.
The reason of this result appears to depend upon the fact that, in this
particular series of experiments, these jars were not watered every day

with a mixture of the two kinds of chemicals, as has usually been my custom. The chemicals were here added on alternate days, as was stated on page 61.

Cotton cloth was employed in these experiments in order that a loose, bulky material that contains no nitrogen might be put in contrast with the bulky nitrogenous matters, such as the leathers and sponge. In case, moreover, any nitrogen from the air had been fixed in the soil, in a manner useful for plants, during the decay of the cotton, — as some chemists formerly thought might be the case, — the crops would have indicated such fixation.

It is to be observed that the product obtained by roasting sheepskin was different from that obtained on roasting sole leather. It was not subjected to so high a temperature, and did not behave like the sole leather at any temperature. The appearance of the roasted sheepskin was unlike that of the roasted sole leather, and the two products differed from one another not a little in respect to their power of absorbing water. The roasted sheepskin repelled water, so that it was difficult to moisten the mixtures of it and sand in the first place, and to keep them properly moistened afterwards, especially at the earlier stages of the experiments when the seeds were germinating. Hence the plants in this set of jars were rather less favorably placed than those in either of the other sets : they had to contend with unfavorable conditions, which, though not very important perhaps, may still have had an appreciable influence on the growth of the crops. Certain empyreumatic matters in the roasted sheepskin may, moreover, have possibly injured the plants a little directly, as any poisonous matter would ; and, on the other hand, it is not unlikely that tanning materials, or other matters, dissolved from the simple leathers, may have done some of the plants a suspicion of harm. It is true, at all events, that the seeds germinated with difficulty in the mixtures of sole leather and sand.

One striking piece of evidence, in proof of the presence of some form of assimilable nitrogen in the roasted leather, was observed, as follows : After the series of thirty jars which contained the mixture of calcined loam and sand, and the various leathers, had been charged and put in position in the glass-house, and watered with nothing but rain-water for a fortnight, in order that the buckwheat seeds should germinate, an abundant growth of a salmon-colored fungus, which my

colleague, Professor Farlow, pronounced to be a species of Pziza, appeared upon the surface of the soil in every one of the jars that contained roasted sole leather; while the most careful scrutiny failed to detect any trace of the fungus upon either of the remaining twenty-five jars in the series. It so happened that the position of these roasted-leather jars was at the very middle of the collection of jars charged with loam and sand. The loam had been calcined and the leather roasted just before they were put in the jars, and neither the jars nor the materials had been exposed to any other air than that of the glass-house. There was no escape from the conviction that the fungus had found something to feed upon in the roasted leather which was absent from all the other jars. But this edible substance could have been no other than some form of nitrogen, since the loam contained all the other elements of plant food. It may here be mentioned that only negative results were obtained on testing some of the freshly roasted leather for ammonia, and for nitrites and nitrates. 20 grms. of the roasted leather were ground to powder in a drug mill, and then boiled in half a litre of pure water, the first 50 cc. of distillate from which were tested with Nessler's reagent. A slight greenish yellow coloration was obtained, together with milkiness, but no trace of the color that is produced by ammonia. 200 cc. of the dark-colored liquor in the flask was decanted and boiled with metallic cadmium in an atmosphere of hydrogen, and, after the removal of the cadmium, distilled with acetic acid, and the distillate tested for nitrous acid, with iodo-starch; but no reaction was obtained. For the sake of controlling this test, a minute quantity of nitrate of potash was added to another portion of the liquor, and the same method was pursued as above: the reaction for nitrous acid was obtained without the least difficulty, in this case.

Several different kinds of sands or soils were used in these experiments, in order, as has been stated already, that the mechanical condition of some one at least of the sets of mixtures might prove favorable for the growth of the plants. The importance of this consideration had been enforced, with perhaps undue emphasis, in the course of a series of experiments with New Jersey green sand, where the texture of the sand seemed to be decidedly unfavorable for the prosperity of the crops. For these experiments nine glass preserve jars were charged as follows: No. I., with 1250 grammes "West Jersey green

sand marl;" II., with 1200 grms. green sand and 40 grms. roasted sheepskin; III., 1130 green sand and 40 roasted sole leather; IV., 1100 green sand and 35 simple sheepskin; V., 1200 green sand and 40 simple sole leather; VI., 1160 green sand and 7 sponge; VII., 800 green sand and 300 anthracite powder; VIII., 1100 green sand and 50 air-dried peat from Bussey farm; and IX., 1250 grms. green sand alone. The roasted leathers were powdered and intimately mixed with the sand, as before, while the shreds of unroasted leather were spread in alternate layers with the sand. Three buckwheat seeds were planted in each jar, February 15, 1875. Jars Nos. 1 to 8 were watered with rain-water throughout the experiment, but jar No. 9 was watered with a solution of nitrate of lime of the usual strength (1 grm. to the litre). The results of these experiments are given in the following table : —

No. and contents of the jar.	The crops harvested April 20, 1875.			
	Weighed grammes.	Grew to height.		Had seeds.
I. Green sand alone	0.085	$2''$ $2\frac{1}{4}''$ $3''$			1
II. G. sand and roast sheepskin	0.085	$1\frac{1}{2}$ 2 $2\frac{1}{2}$			0
III. G. sand and roast sole leather . . .	0.780	3 $8\frac{1}{2}$ $8\frac{1}{2}$			14
IV. G. sand and simple sheepskin . . .	0.100	$2\frac{1}{2}$ 3 $4\frac{1}{2}$			0
V. G. sand and simple sole leather . .	0.115	2 3 $3\frac{1}{2}$			0
VI. G. sand and sponge	0.060	2 $2\frac{1}{2}$ 5			0
VII. G. sand and anthracite	0.110	$2\frac{1}{2}$ 3 6			1
VIII. G. sand and peat	0.445	$4\frac{1}{2}$ 5 5			10
IX. G. sand and nitrate of lime	3.930	$12\frac{1}{2}$ $13\frac{1}{4}$ 19			56*

* And many flowers.

Here, as in the other experiments, the roasted sole leather manifestly supplied some nitrogen to the crop. There seemed indeed to be a good deal of nitrogen at the disposal of the plants in that jar (No. 3), but it was especially noteworthy that the plants did not profit by it much until they had become rather old. Thus on the 13th March, almost a month after the seeds had been sown, the plants in jars Nos. 1 to 6 were all very poor, and on the 23d March, although jars Nos. 3, 7, and 8 were rather better than the rest, except 9, it was still true that there was not a jar in the green sand series, excepting No. 9, that had so good a crop as several that were growing close at hand in calcined loams from various sources, in which buckwheat seeds had been sown two days later than in the green sand, and which had been watered with rain-water without addition of any other substance.

On the 29th March, one of the plants in jar No. 3 was taken up, dead. Yet, at the time of harvest, the crops from the calcined loams weighed only from 0.15 to 0.195 grm. ; while the crop from the mixture of green sand and roasted leather weighed 0.78 grm., in spite of the premature death of the plant just mentioned.

As regards the roasted sheepskin, in jar No. 2, it was plain from the appearance of the plants that this material actually did harm in the earlier stages of growth. One of the plants in this jar died before the end of March, and another somewhat later. But the plant finally harvested, though very small, was green in all its parts, and had evidently procured a little nitrogen, in some form, from the roasted sheepskin.

At the time when this series of experiments was made, it was thought that the peculiarly wretched appearance of the crops might be due in some part to the compact character of the green sand : it lay dense and heavy in the jars, and its closeness of texture seemed to have some connection with the manifest distress of the plants. But the results obtained since that time with the mixture of calcined loam and sand, as given above, in which the well-fed plants prospered, and the ill-fed did not prosper, as well as the large weight of the crop that was obtained from the green sand by means of nitrate of lime (jar 9), go to show that the small crops from the green sand were really due not so much to bad mechanical condition of the soil as to an actual want of nitrogenous food.

The general conclusion to be drawn from all these experiments seems to be, that while ordinary leather is absolutely worthless as a fertilizer, roasted leather has a certain small value, depending upon the presence in it of some form of assimilable nitrogen. It would be of interest to determine, by analysis, what the substance or substances really are in the roasted leather which are useful to plants, to ascertain how much of them are present at the best, and to determine what temperatures are most favorable for their formation. But there is nothing in the present investigation, nor is there elsewhere any evidence that I know of, to invalidate the common impression that nitrogenous plant-food can probably be obtained both in larger quantity, and at a cheaper rate, by distilling leather with soda-lime or potash-lime, than by any method of mere roasting, without addition of chemicals.

There is but little, moreover, in the results above given, to encourage

the belief that roasted leather can have any definite money value as a manure. On comparing these results with those given on page 258, Vol. I., of this Bulletin, it will be seen that, under the conditions which obtain in these experiments, plants can get a supply of nitrogenous food from ordinary loams and peats about as well as they can get it from the roasted sole leather. The experiments upon sponge and anthracite were too few in number and too little varied in kind to give results of any importance, and the results actually obtained were not of a nature to encourage further research. Both the sponge and the powdered anthracites, especially the anthracite with which no sand was admixed, seemed to yield some traces of nitrogenous food to the plants, but these traces were very faint. It can be said only that the crops obtained from the sponge and the anthracite were a little better, or tended to be a little better, than those from the cotton or the unroasted leathers.

It was noticed that the buckwheat seeds germinated uncommonly well in the powdered anthracites, to which no sand had been added, apparently because of the lightness of this material, which permits the rootlets of the seedling to move freely among its particles. It is not unlikely that anthracite dust, sifted to a proper size and washed free from impurities, may be found to be better fitted for striking cuttings, in some cases, than the sand ordinarily employed to that end by florists.

No. 6. — *Notes of Experiments in which Buckwheat Plants were watered with Solutions of Peat in Alkalies.* By F. H. STORER, Professor of Agricultural Chemistry.

IN the hope of adding something to the existing stock of knowledge as to the causes of the well-known beneficial action of alkalies upon peat in composts, I have tried a few experiments to test the question whether solutions of peat in alkalies have any direct or immediate power of supplying plants with nitrogenous food. To this end solutions of "crude peat" and of "leached peat" were prepared as follows : A quantity of air-dried peat from the Bussey Farm was divided into two parts ; one part was boiled repeatedly with fresh portions of dilute chlorhydric acid, prepared by mixing one volume of the strong commercial acid with one volume of rain-water, and was afterwards washed thoroughly with rain-water, and allowed to become completely dry in the glass-house in which the culture experiments were to be made. A considerable quantity of each of the peats was finely powdered, so that the portions weighed out for the experiments were known to be homogeneous.

I. 10 grammes of the air-dried leached peat were boiled for three quarters of an hour in one and a half litres of water, in which 0.375 grm. of triphosphate of potash had previously been dissolved.

II. 10 grms. of the original unleached (so called, crude) peat were boiled as above with one and a half litres of the solution of phosphate of potash.

III. 10 grms. of the crude peat were boiled, as above, with one and a half litres of water in which 0.375 grm. of anhydrous carbonate of soda had previously been dissolved.

IV. 10 grms. of the leached peat were boiled, as above, with carbonate of soda.

The solutions were filtered into large wash-bottles, such as chemists use, and kept in the glass-house. Solutions Nos. 1 and 2 were of a light yellow color, while Nos. 3 and 4 were very dark, *i.e.* almost or quite black. In this instance, as in so many others, the phosphate of potash manifestly acts as a weak alkali, — one very much weaker than the carbonate of soda. It is to be observed that the long-continued boiling with the alkaline solutions would expel from the peat any

ordinary salt of ammonia that might have been contained in it ready formed, or, at the least, this remark would be true of the carbonate of soda.

Five wide-mouthed glass jars (preserve jars) were charged each with a mixture of 760 grms. Berkshire sand and 560 grms. of garden loam that had been calcined in a muffle to free it from organic matter. Two buckwheat seeds were planted in each jar, Jan. 5, 1876; and the jars were watered with rain-water until the seeds had sprouted, and the young plants had acquired a firm foothold. Thereafter the plants were watered with the solutions of peat above described until April 3, when the experiment was finished, excepting jar No. 5, which was watered with rain-water throughout the experiment. The numbers upon the jars corresponded with those of the solutions, as above given. The results of these trials are given in the following table : —

No. of Jar.	The jar was watered with a solution of —	The crop harvested April 3, 1876, and dried at 90° to 100° C.		
		Weighed grammes.	Grew to height.	Had seeds.
1	Leached peat in phosp. potash .	0.170	3½″ 5½″	0
2	Crude peat in phosp potash . .	0.150	4½ 4½	0
3	Crude peat in carb. soda . .	0.220	5½ 6	0
4	Leached peat in carb. soda . .	0 200	5½ 6½	1
5	Rain-water	0.185	4 6	1

At no time during these experiments could it be said that either of the crops watered with the peat solutions were growing any better than the one that got nothing but rain-water, though the plants in jars Nos. 3 and 4 were a shade better-looking than those in jars Nos. 1 and 2 : still, the slightly larger weights of the crops from jars 3 and 4, which were watered with the dark-colored solutions of peat in carbonate of soda, taken in connection with the fact that only two plants were grown in each jar, goes to show that a minute trace of nitrogenous food was supplied to these two crops by the solutions. But the trace of nitrogen thus supplied was hardly appreciable, and must have been exceedingly small. Practically speaking, it may be said, without hesitation, that the results of all these experiments point to the conclusion that solutions of the Bussey Farm peat in alkalies do not supply nitrogen to plants. The only suspicion of doubt as to this matter arises from the comparatively small absolute amount of peat that was taken in each instance for preparing the solutions. Had a

hundred grammes of peat been taken instead of ten for the given amounts of water and alkali, it is not impossible that more nitrogenous food might have been made available for the plants.

It is worthy of remark, with regard to the crops that were watered with solutions of peat in carbonate of soda, that both of the plants in jar No. 4, and one of those in jar No. 3, had the peculiar reddish-brown leaves that have been noticed by other observers who have grown plants in peat, and often by myself in previous experiments. It should be said, furthermore, that, towards the close of the experiments, moulds were observed to be growing in the wash-bottles that contained the peat liquors, particularly in the one that held the solution of crude peat in carbonate of soda. Indeed, the color of that special solution was finally changed from the original black to as light a yellow as that of the solutions of peat in phosphate of potash. The solution prepared with leached peat and carbonate of soda retained its dark color. There was nothing to indicate that the growth of this fungus had interfered in the least with the conduct of the experiments as above described, or that it had exercised any appreciable influence whatsoever upon them; but the fact of the growth of the mould is interesting in itself, as showing that some of the lower orders of plants can procure nitrogen from the alkaline peat liquors or from the products of their decomposition.

The results of the foregoing experiments go to show that the nitrogenous constituents of composts prepared with peat and alkali, which are known from practical experience to serve an excellent purpose as plant food, are probably products of the decomposition of the peat through fermentation caused by the alkali, — as was indicated before by the experiment of Angus Smith,[*] and by the prevailing method of preparing composts, of which fermentation is an essential feature, — and that they are not mere educts from the peat held in an alkaline solvent. That peat alone, without the addition of an alkali, can supply a great deal of nitrogen to crops in soils that are well supplied with the other kinds of plant-food, and are favorably situated with respect to warmth and moisture, has been sufficiently insisted upon already in an article printed on page 252 of the first volume of this Bulletin.

7. — *Remarks on some Algæ found in the Water Supplies of the City of Boston.* By W. G. FARLOW, Assistant Professor of Botany in Harvard University.

IT will be remembered that, in the months of October and November, 1875, a peculiar taste was noticed in the drinking water of the City of Boston, which was generally described as resembling that of cucumbers. It is recorded that a similar taste was noticed in the autumn and winter of 1854; and, at that time, an investigation was made concerning its origin. The investigation, conducted by well-known chemists, did not result in assigning any definite cause for the taste; and in hinting that it might have arisen from Crustacea in which had been noticed a quantity of oil globules, the chemists were expressing an opinion which could only have weight when coming from a zoölogist.

When the taste reappeared in 1875, an examination of the water was made by Professor W. R. Nichols, Mr. Edward Burgess, and myself, to ascertain whether any substance known to chemistry, zoölogy, or botany, could have produced the peculiar cucumber taste. The results of our examinations are given in the " Report of the Cochituate Water Board," Boston, 1876; and it needs only be said, in this connection, that no assignable cause could be discovered, but that, as far as the botanical examination showed, the water was unusually pure; that from the Bradley Basin, where the cucumber taste was strong, being decidedly more free from vegetation, whether living or dead, than that from the Brookline Basin where the taste was not perceptible. Inasmuch as the subject of fresh-water algæ is a *terra incognita* to water boards, upon whom not unfrequently devolves the duty of explaining to the public the cause of various unpleasant smells and tastes, it seems not inappropriate to say a few words about what is known of the relation of those plants to smells and tastes, even if it should amount to a confession of a very considerable ignorance.

It has long been believed, by that part of the public which is interested in botany, that the algæ known as nostocs have a disagreeable odor, and, in many cases where unpleasant odors have arisen in bodies of water which serve as water supplies, it has been considered a sufficient explanation to say that the odor is produced by some nostoc-like plant, without, however, going so far as actually to find

the plant which is supposed to be a nostoc. Undoubtedly, the most disagreeable odor ever found in fresh water may be produced by nostocs, using that word to designate the order *Nostochineæ;* but by no means all of the disagreeable odors and tastes arise from that source. To return to the cucumber taste, there is not the slightest proof that it is caused by any algæ, either living or decaying. The water from the Bradley Basin showed no nostocs whatever, and no algæ of any kind not also found in waters which did not have the cucumber taste. During the past summer, we have made experiments to ascertain the taste produced by different species of algæ. For this purpose different species of *Desmidieæ, Confervæ,* and *Oscillariæ,* were allowed to stand several weeks in glass jars filled with pure water; but, in no instance, was any thing like a cucumber taste produced, nor, in fact, was any describable taste perceived.

As far as smells are concerned, our knowledge is more complete. It is known that, when living, different species of nostoc may produce two different kinds of disagreeable odors : first, an indescribably suffocating odor, as in the case of several *Lyngbyæ* and *Oscillariæ ;* and secondly, a sulphurous odor, as is given off by species of *Beggiatoa.* A still more disagreeable odor is given off by species of nostoc in decay, an odor resembling that of a pig-pen or very strong horse-dung. Most persons who have in midsummer walked through the bogs so common in New England must have recognized the stifling odor given off by the bluish-green masses growing on the mud or in shallow water. These are usually species of *Oscillaria,* composed of filaments made up of small cells in rows, the filaments capable of moving on one another, so that, when placed on any flat surface, they push out from one another, and spread over a larger area, or, if placed on the bottom of a tumbler, they crawl up the sides. The chemical nature of the stifling odor is not known. This peculiar stifling quality is not peculiar to nostocs, or even to fresh-water plants. It is marked in several marine plants, as *Polysiphonia fastigiata,* which forms blackish tufts on the larger rock-weed.

The algæ which exhale sulphurous odors belong to the genus *Beggiatoa,* which resembles *Oscillaria* in consisting of filaments endowed with motion, but which differs in color, being whitish, the cells being full of opaque granules. They look to the naked eye like white films covering decaying algæ and other plants. They are found on

the sea-shore as well as in fresh water, but are particularly common in hot springs. Cohn has shown that the peculiar exhalations of hot sulphur springs are owing to the growth of species of *Beggiatoa*,[*] which depend for their existence upon, at least, two conditions; the presence of a large amount of sulphur in the water, and the absence of iron. Cohn confirms the observations of Cramer, that the dark granules in species of *Beggiatoa* consist of sulphur. When *Beggiatoa* filaments are heated, the granules fuse into large yellowish drops and a sulphurous odor is developed. If the filaments are treated with sulphide of carbon, the granules are dissolved, and then the cell partitions become for the first time visible.

The odor produced by decaying algæ of the order *Nostochineæ* was brought most strikingly to our notice during the last summer. In the month of August, we were asked to examine the waters of Horn Pond, situated in the town of Woburn, nine or ten miles from Boston, and the head-waters of what is known as the Mystic basin, which supplies Charlestown and East Boston. It was stated that a disgusting odor, said to resemble that of a pig-pen, had appeared in several portions of the pond. On inquiry, we found that there had been a quantity of a plant called eel-grass washed ashore, and upon it was a slimy mass from which the odor seemed to proceed. The slimy masses were not limited to any particular part of the pond, and, although very abundant at the upper end, they were also common at the outlet. At the time of our visit they were said to be by no means as numerous as two or three days before. The eel-grass, so called, to our great surprise, proved to be not what is generally known by that name (*Vallisneria spiralis*) or even any of the common pond-weeds (*Potamogeton, Myriophyllum, Ceratophyllum*), but a new species of *Plectonema*,[†] of the order *Nostochineæ*, which we had never seen growing

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[*] For an account of the physiological and chemical relations of the genus *Beggiatoa*, vid. " Beiträge zur Biologie der Pflanzen," by Cohn, Vol. 1, Part III., pp. 172–180, where references are given to the earlier writings of Cohn and others on this subject.

[†] *Plectonema Wollei*, n. sp. Trichomatibus atro-viridibus in massas pluripedales intricate coalitis ; ramis parcibus obtuse exeuntibus plerumque singulis rarissime geminatis. Trichom. diam. .00388 m. m.; c. vagina .00405; articulis circa .000485 m. m. latitudine. Species magnitudine et ramis parcibus facile distincta. Species generis nobilissima a cel. Wolle prope Bethlehem in Pennsylvania primum inventa est. Ad Horn Pond prope Boston detexi. Species a cel. Rabenhorst in Algis Europæis, no. 2440, sub nomine *Lyngbya Wollei*, Farlow, distributa est.

before, and which was first observed by the Rev. Francis Wolle in the waters near Bethlehem, Pa. It grew in great abundance at the head of the pond where the water was shallow, attached to other plants and sticks, and spread over the surface in areas of several square feet, forming blackish green patches like the plant called mermaid's hair (*Lyngbya majuscula*) on the sea coast, only very much more luxuriant. Where the *Plectonema* was free from the slimy substance, it emitted the suffocating smell of many of the *Oscillariæ*, but was free from the pig-pen odor.

In various places along the edge of the pond, and in some places where the *Plectonema* came to the surface, were masses of slime, at first of a pale bluish-green, afterwards of a brownish color. The odor was most disgusting, and resembled rotting horse-dung to such an extent that it was difficult to believe that it came from a vegetable substance. A microscopic examination showed that the slime was composed of an amorphous mucus, in which were the threads composed of the heterocysts and hormogoniæ peculiar to the *Nostocs* proper, but, unfortunately, in a too advanced stage of decomposition to be specifically determined. An examination of the water of the pond showed it to be full of little rods, which shone in the sunlight. These rods had the same microscopic structure as the filaments of the slimy masses which were evidently aggregations of decaying filaments, which, in a normal condition, float freely in the water. At the time of our visit, however, even the filaments which were still floating, were so far disintegrated that, after an unavoidable journey of several hours in the cars, they were not in a condition to be specifically determined. We are entitled to assume that the alga was a species of *Anabæna* or some nearly related genus, perhaps *Nodularia litorea*, Thuret, the decomposition of large quantities of which produced an intensely disagreeable odor near Deauville, Normandy, in August, 1874, as we learn from Dr. Bornet.

Early in October, we again visited Horn Pond, with the purpose of obtaining some of the *Anabæna*, if possible. It had, however, completely disappeared. Furthermore, the *Plectonema*, which in August was attached, was washed ashore in immense quantities, leaving the surface of the pond clear. A quantity of the *Plectonema* was kept for some time until it began to decay, when that too began to give off an odor of pig-pen, which could hardly have arisen from any remains of

the *Anabæna*, as a microscopic examination showed no traces of it. It would seem then that the peculiar odor, which was so marked in the case of Horn Pond, may arise from decay of more than one species of the *Nostochineæ*, and the probability is that a large number of species may produce it. The important point is, that it is during their decay that the odor is found; not while they are growing. The question arises as to what killed the algæ so suddenly. Those living near the pond are quite ready to believe that it was the refuse from the tanneries, but there is no proof whatever that that was of a different character from what it had been previously, and the question is still open, why at that particular time the algæ were killed. It will be remembered that, during the month of August, 1876, the heat was excessive, and the temperature of the surface water was raised considerably. We cannot doubt that the broiling rays of the sun had a destructive effect on the *Anabæna*, especially that which was caught in the meshes of the *Plectonema*, and, by the falling of the water consequent upon the drought, exposed on the surface.

From the preceding account of the condition of Horn Pond, we are warranted in drawing certain conclusions which may on some occasion prove useful to water boards. If a sudden odor of pig-pen arises, it is in all probability owing to the decay of large quantities of some algæ of the nostoc family, and most probably one of the finer species diffused through the water. As the decay is generally, if not always, brought about by causes beyond human control, it is useless to try to stop it when it has once begun. On the other hand, there is no occasion for great alarm; for, when they have once begun to decay, algæ like *Anabæna* disappear in a few days. In the case of Horn Pond, we understand that the odor lasted barely a week from the time when it was first perceptible. As to the possibility of the putrescent masses being carried any great distance, in the case of Horn Pond it was found that they advanced as far as Winchester, not more than two miles in a direct course, but were not found farther on. They never made their appearance in Charlestown or East Boston. Knowing that floating algæ are caught in the meshes of *Plectonema* and other similar filamentous algæ, and thus, during the sinking of the water, which usually occurs in July and August, exposed on the surface to the direct heat of the sun's rays, which cause them to decompose, it is evident that it is a useful precaution to remove, as far as possible, the

long filamentous algæ and fine-leaved phanerogams. No plant of our waters is of such large size, or of such fine meshes, as the *Plectonema Wollei*, which, although as yet recorded in only two localities, will probably prove common enough. It is a summer plant, and does not attain considerable dimensions before July. It starts on the stems, leaves, and old sticks on the bottom, and forms coils several feet in length. On reaching the surface, it expands over considerable areas. In the latter part of September, it breaks away from its attachments, drifts ashore, and disappears to return the next summer.

In conclusion, a word about another plant common at Horn Pond, and which has been sent to us from several localities, with inquiry as to its nature. It forms a bluish or yellowish green scum on the water, often spread over a considerable area. Were it not that it forms such a thin layer, it could be collected in large quantities. Kept in bottles, it multiplies and forms irregular masses of a pea-green color and mealy consistency. At first solid, the superficial cells imbedded in a gelatinous mass increase rapidly, and it becomes hollow. Then certain portions project like buds, and finally separate from the mother plant, which seems to be perforated. This plant, *Clathrocystis æruginosa*,[*] was described by Henfrey, and is now classed by Cohn amongst the Bacteria, and placed near *Clathrocystis roseo-persicina*, a plant which forms purplish red films on decaying algæ, and on the ground along our coast, and which in Europe is also found in fresh water, but it has not yet been found in the interior of our own country. We mention it from its frequent occurrence, and because it has been supposed to injure the water in some places. There is no account of any injury having been done to man; but in Germany, where it is known as the *Wasserblüthe*, it has been destructive to fishes. Cohn [†] suggests that the slimy substance of which it consists, forms a coating over the fish, and shuts off the supply of air necessary to support life. Professor Hagen, of Cambridge, suggests, as a remedy, the introduction of snails into water where it occurs, as they are extremely voracious, and eat large quantities of fresh-water algæ.

[*] "Trans. of the Microscopical Society of London," 1856.

[†] "Aus neuester, wie aus älterer Zeit besitzen wir Nachrichten, dass die Fische in einem Teiche, welcher mit der Wasserblüthe dieser alge sich bedeckt, massenhaft absterben; vielleicht wird durch die dicke Schleimhaut die Aufnahme des für das Athmen der Fische unentbehrlichen Sauerstoffs aus der Luft gehemmt." Beitrage zur Biologie, Vol. 1, Part III., p. 155.

No. 8. — *On the Composition of certain Pumpkins and Squashes.* By F. H. STORER, Professor of Agricultural Chemistry.

THE common yellow field pumpkin has always been conspicuous in the agriculture of New England, where it is highly esteemed for feeding cattle and swine during the autumn and early winter, or as long as it can be preserved from decay.

"Pumpkins are raised especially for the use of cows and fatting cattle. They increase and enrich the milk, whether for butter or cheese." (*New England Farmer*, 1829, **7**. 225.) "They are valuable as affording an early supply of food, for feeding horses and fattening all sorts of cattle in the fall and fore part of the winter before the ruta-baga crop should be used. If steam-boiled, they are a rich food for swine." (*New England Farmer*, 1827, **5**. 294.) "For feeding to milch cows in the fall, we do not know of a better article according to their cost; for feeding to beef cattle they are excellent, and when boiled and mixed with a little Indian meal, they excel most kinds of food for feeding hogs." (*New England Farmer*, 1831, **9**. 311.) "For producing rich milk, the old-fashioned yellow field pumpkin is one of the very best articles that can be given to cows. Fed raw to hogs, pumpkins are useful by increasing the appetite. They will fatten young fall beef, and give fatting oxen a better start than either potatoes or turnips." (*New England Farmer*, 1844, **22**. 372.)

The cultivation of the pumpkin seems to have been inherited from the Indians * by the first settlers of the country, together with that of maize, and to have been persisted in thenceforth by our farmers, in spite of the competition of other kinds of crops that might have been cultivated in its place. It is noticeable, moreover, both of Indian corn and of pumpkins, that the cultivation of them here in New England has been kept up in good measure even to the present time ; and that the great changes in the agriculture of the region, brought about of late years through the importation of cattle, grain, and fodder from the Western and Southern States, have been powerless to exclude either of these familiar plants from our fields.

It is manifest that, in order to the right understanding of the agriculture of this country, the composition of both these crops should be clearly ascertained. In respect to Indian corn, this knowledge has

* Compare T. W. Harris, in "New England Farmer," and U. S. Patent Office Report, 1854, p. 208.

already been gained in good part. That is to say, the average chemical composition of the maize plant, both stalk and grain, has been determined with a considerable degree of accuracy.*

Some attention has been paid to the composition of pumpkins, also, by European chemists, as will be shown directly. But I have nevertheless found myself in some doubt, when speculating upon the foddering practices of New England, as to what value should be allotted to the pumpkins grown in this country, and have on this account been led to investigate the question anew. For the sake of contrast, I have had analyses made of the common marrow squash of the vicinity of Boston, of the Hubbard squash, and of the crook-necked squash.

The pumpkins analyzed were the common round yellow varieties. They were grown upon farms not far from the Bussey Institution, and were obtained in the middle of October, 1876. Both the large and the small kinds of pumpkins were examined, as will appear from the statements below. Both with the pumpkins and with the squashes that are to be described hereafter, the flesh, the rind, and the inside portion, consisting of the seeds with the loose stringy matter that is attached to them, were examined separately; and, in order to obtain fair average samples of these materials, two individual pumpkins or squashes were operated upon in each case.

I. *Large Pumpkin.* Specimen *a* weighed 14 kil. (nearly 31 lbs.), and was 11×14 inches in diameter. Specimen *b* weighed 8¼ kil. and measured 10×12 inches. The flesh of *a* was noticeably coarse-grained, and rather spongy, though perfectly sound. In order to obtain material for the analyses, the pumpkins were cut in halves lengthwise, and the contents of the seed cavity were removed by scraping with a porcelain dish. Quantities of this inside matter were immediately weighed out for the estimation of moisture. The remainder of the vegetable was then sliced lengthwise, and the rind pared off to the depth of about a millimetre; portions of the flesh and of the rind being taken from different

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* Compare Atwater, "American Journal of Science," 1869, **48.** 852; the tables in Johnson's "How Crops Grow," p. 386; and those in Dietrich and Kœnig's "Zusammensetzung der Futterstoffe," Berlin, 1874, pp. 4, 27. Exclusive of the work of Atwater, and that cited by Johnson, Dietrich and Kœnig report twelve different analyses of maize grain, and eight analyses of fodder corn, made by a number of different chemists. There have been several other analyses published still more recently.

Since this note was written an important paper on fodder corn, by Professor S. W. Johnson, of New Haven, has been published in the "American Journal of Science." March 1877, (3.) **13.** 202.

parts of the vegetable, for the estimation of moisture. The amounts of moisture found in the fresh vegetables by drying at 110° C. were as follows: The larger pumpkin (*a*) contained 91.66% water in the flesh, 82.33% in the rind, and 71.72% in the inside matter (seeds, &c.); while *b* contained 93.16% in the flesh, 86.54% in the rind, and 80.15% in the inside portion. The mean percentage of water was 92.41 in the flesh, 84.44 in the rind, and 75.94 in the inside portion.

For the analyses proper, a number of sections of the flesh, cut from the stem mark to the flower mark, were taken from each specimen. The sections were dried together, and finally ground together to a homogeneous powder, which was the material analyzed. A mixture of rind was obtained in the same way, by taking portions from each of the two pumpkins. But the entire contents of both the seed cavities were dried and ground together for the analysis, excepting the portions used for determining the original moisture. The total amount of seeds, &c., found in *a* was 548 grms. while in *b* there was 588 grms.

II. *Smaller Pumpkin.* Specimen *c* weighed 4½ kil., and measured 8×10 inches in diameter. Specimen *d* weighed 5 kil., and was 9×10 inches in diameter. The total weight of seeds and stringy matter taken from the internal cavity was 510 grms. in *c*, and 520 grms. in *d*. The amount of moisture found in *c* was 94 57% in the flesh, 87.49% in the rind, and 77.80% in the inside matter; in *d* the amounts were 88.53% in the rind, and 77.78 in the seeds, &c., the amount of moisture in the flesh not having been determined in this instance. Hence the mean percentages of moisture in the small pumpkins may be taken at 94.57 for the flesh, 88.01 for the rind, and 77.79 for the inside matters.

The composition of the flesh, the rind, and the seeds and stringy substance of the pumpkins, taken in their natural undried state, will appear from the following figures: —

Pumpkin Flesh.	I.	II.	Mean of the two Analyses.
Water	92.41%	94.57%	93 49%
Ash (free from C and CO_2) .	0.71	0 63	0.67
Albuminoids	0.87	0.75	0.81
Carbohydrates (including fat)	4.90	3 19	4.04
Cellulose (free from ash) .	1.11	0.86	0.99
	100.00	100.00	100.00
Dry organic matter . . .	6.88	4.80	5.84
Fat (ether extract) . . .	0.10	0.14	0.12
Nitrogen	0.14	0.12	0.13
Crude ash	0.80	0.73	0.77

Pumpkin Rind.	I.	II.	Mean of the two Analyses.
Water	84.44	88.01	86.23
Ash (free from C and CO_2) .	1.50	1.23	1.36
Albuminoids	2.90	2.63	2.76
Carbohydrates (including fat)	7.24	5.16	6.20
Cellulose (free from ash) .	3.92	2.97	3.45
	100.00	100.00	100.00
Dry organic matter . . .	14.06	10.76	12.38
Fat (ether extract) . . .	0.49	0.49	0.49
Nitrogen	0.46	0.42	0.44
Crude ash	1.58	1.26	1.42

Pumpkin Seeds and Stringy Matter.	I.	II.	Mean of the two Analyses.
Water	75.94	77.79	76.87
Ash (free from C and CO_2)	1.66	1.36	1.51
Albuminoids	6.32	5.68	6.00
Carbohydrates (including fat)	12.34	11.05	11.69
Cellulose (free from ash) .	3.74	4.12	3.93
	100.00	100.00	100.00
Dry organic matter . . .	22.40	20.85	21.63
Fat (ether extract) . . .	7.13	6.71	6.92
Nitrogen	1.01	0.91	0.96
Crude ash	1.68	1.38	1.53

The most noteworthy feature of these analyses is that the proportion of albuminoids is shown to be very much larger (nearly $3\frac{1}{2}$ times as large) in the rind of the pumpkin than in the flesh. The flesh, which constitutes by far the larger part of the vegetable, is by no means extraordinarily rich in nitrogenous matters. It will be seen at a glance that the weight of the albuminoids in the flesh amounts to only about a fifth as much as that of the carbohydrates, which is a proportion that has sometimes been found in turnips.* It is manifestly unfair, therefore, to class the pumpkin as a highly nitrogenous food, as has been done hitherto. It would seem to be plain, moreover, that a large part of the nitrogen found in pumpkins by previous analysts must have been contained in the rind (or in the seeds), and that the chemists in question examined either the entire vegetable or the flesh and rind of

* Compare Wolff's table in Johnson's "How Crops Grow," p. 387.

it taken together. It is known, indeed, that this conception is true of some of the analyses which will be cited directly, and there can be little doubt that it is true of all of them. But since the constituents of the rind are in all probability much less easily digestible than those of the flesh, it follows that analyses of mixed flesh and rind are ill suited to convey a just conception of the fodder value of the vegetable.

The following table comprises some results of foreign analyses of pumpkins which appear to be trustworthy. See further the analyses cited on pages 90 and 91.

Name of the Analyst.	Per cent of Water.	Albuminoids.	Carbohydrates, including Fat.	Cellulose.	Fat.	Crude Ash.
Braconnot*	93.48	. . .	4.06	1.32	0.06	0.75
Braconnot*	95.40	. . .	2.85	0.93	0.04	0.56
Zenneck*	89.50	. . .	. . .	1.59	. . .	1.58
Mosert†	94.50	1.30	2.20	1.00	0.10	1.00
Voelcker‡	92.98	1.53	3.24	1.65	0.73	0.60

Girardin § reports, 94.18 — 85.80 — 92.94 — and 93.40% of water in four varieties of pumpkins examined by him. It has, in fact, been pretty thoroughly proved that the amounts of water contained in pumpkins, squashes, melons, and the like. are subject to rather wide variations. Dr. Vœlcker has already remarked, when reporting his analyses ‖ of the " American Cattle-Melon " [quære, Citron Water-Melon ?] that " the proportion of water in the cattle-melon, as in other succulent vegetable

* Liebig and Kopp's " Jahresbericht der Chemie," 1847-'48, 1. 830.

† Cited in Werner's " Handbuch des Futterbaues," Berlin, 1875, p. 725; and not quite correctly by Wolff. A misprint in Wolff's original tables, whereby the item carbohydrates is stated as 2.8, instead of 2.2, has been widely copied. Dietrich and Kœnig, for their part (p. 78 of their tables), have fallen into a much worse error by writing 7.5% of dry substance, instead of 5.5%, whereby all their figures relating to the pumpkin were perverted. I regret having copied these erroneous figures upon p. 367 of the Bussey Bulletin, Vol. I.

‡ Cited in Werner's " Futterbau," p. 725.

§ Liebig & Kopp's " Jahresbericht der Chemie," 1849, 2. 485.

‖ " Journal of the Royal Agricultural Society of England," 1865, 1. 147. Compare Hoffmann's " Jahresbericht der Agrikultur-Chemie," 1864, 7. 281, 1865, 8. 815 ; and Henneberg's " Jahresbericht für 1865-'66," p. 112.

productions, is subject to considerable variations: as far as my experience goes, it is much larger than in mangolds, approaching more nearly to the character of white turnips."

It will be noticed that the analyses of Moser and of Vœlcker show an amount of albuminoids nearly half as large as the amount of the carbohydrates, which is a rather better proportion than has been found in peas. The mere mention of this fact is enough to condemn the indications of the analyses; since, no matter how high the estimation in which pumpkins are held by farmers, it is manifest that they are not to be classed with peas as a foddering material.

The large proportion of nitrogen contained in the inside or offal portion of the pumpkin is not at all surprising in view of the well-known tendency of compounds of this element to accumulate in the seeds of plants. The large percentage of oil also in the seeds was to have been expected in view of their well-known oily character. Oil of pumpkin-seed has in fact often been prepared in this country, upon the manufacturing scale, by subjecting the seeds to pressure in the cold, much in the same way that oil is expressed from rape-seed, flax-seed, and walnuts. Compare " New England Farmer," 1825, **3.** 42; 1828, **7.** 163, and 1841, **20.** 141. It is a palatable salad-oil, according to Langethal and other German authorities.

The presence of such large amounts of oil and of albuminous matters would naturally go to show that pumpkin seeds must be a highly nutritious kind of food; and it may well be true that they are valuable for some kinds of animals when administered carefully and in moderate quantity. But it has often been urged that the seeds of pumpkins are apt to do harm to animals that have eaten them. Thus, for example, one writer in the "New England Farmer" (1827, **5.** 294. Compare 1832, **11.** 150.) urges that the seeds should be taken out from pumpkins that are to be fed to hogs, since they prove injurious to these animals. Another writer ("New England Farmer," 1860, **12.** 159) maintains that pumpkin seeds are poisonous to many fowls, and cause death. Mr. Russell, in his work on North America and its Climate (Edinburgh, 1857, p. 49), reports the impression he received from our farmers that pumpkin seeds have an injurious action on the kidneys when cattle are fed long upon them.

Although the idea that pumpkin seeds are generally injurious to animals has sometimes been denied, there can be little question that it

is to a certain extent founded in fact; since the seeds are known by physicians to possess diuretic properties, and are sometimes used in this sense as a medicament. They are esteemed, also, for expelling tapeworm * from the human subject, though it has often been urged in this connection that the seeds are preferable to other medicines that might be used for this purpose, because they are mild and innocuous, and cannot possibly do the patient any harm.

It would be of interest to determine carefully by observation and experiment the limits — both as to the quantity of food consumed and the length of time during which the food is administered — within which the seedy portion of pumpkins may be safely given to animals. As matters now stand, the practices of our farmers seem to indicate that the danger in using the seeds must be both small and remote. Excepting in the case of milch cows, to be mentioned directly, pumpkins are usually fed out without thought of their seeds. So far as my own information goes, it seldom happens that pains are taken to exclude the seeds from the rations of fatting cattle or swine; on the contrary, the latter are pretty sure to receive the seeds of those pumpkins and squashes whose flesh has been consumed in the farmer's household. As is well known, pumpkin seeds are rather palatable. They are relished by many children, as well as by mice and swine. According to Pumpelly,† the kernels of pumpkin seeds are eaten by the Chinese at the intervals between courses at dinner. He reports that the seeds are so much used in this way in China, that they form an important item in the trade of certain provinces. In Egypt also, travellers report that pumpkin seeds are eaten much in the same way that nuts are eaten in other countries. Mr. J. N. Smith ‡ of South Walpole, Mass., in reporting some excellent results obtained by him in fattening swine with raw pumpkins, remarks, "some say that the seeds of pumpkins must be taken out, or they are an injury to cattle. I would say, in relation to this, that I noticed in feeding my pumpkins to my pigs, that they would eat the seeds first, when not very hungry."

Beside the general idea just alluded to, that pumpkin seeds may be hurtful to any kind of animal, there is a wide-spread impression that

* See "United States Dispensatory" of Wood & Bache, and the "American Journal of Pharmacy," *passim.*

† "Across America and Asia," New York, 1871, p. 302.

‡ "New England Farmer," 1863, **15.** 70; compare 1862, **14.** 541.

they are apt to "dry up" * milch cows, and it is a not uncommon, though by no means a universal, practice of our farmers to remove the seeds from those pumpkins that are to be given to cows. This practice finds manifest justification in the diuretic property of the seeds, just now alluded to; for, where the action of the kidneys is increased by a medicament, it is but natural that the secretion of milk should lessen.

The squashes which were analyzed in comparison with the pumpkins, were obtained at the same time as the latter, and were grown in the same neighborhood. They were prepared for analysis in the same way that the pumpkins were prepared, with the exception that the rind of the squashes was removed by paring, as a potato would be pared, before the vegetables were cut open. This method of operating was found to be more rapid than the other, and to yield a somewhat thinner rind. The whole of the rind obtained from each lot of squashes, excepting what was used for estimating the natural moisture, was dried and ground together for the analysis, and the same remark is true of the seeds and stringy matter. The sizes and weights of the several squashes will appear from the following statements.

The Marrow Squashes weighed 5¼ and 3 kil. respectively. The larger one measured 9×10 inches, and the smaller 7×9 inches. The seeds and stringy matters taken from the cavity of the large squash weighed 475 grms., and those from the smaller squash 446 grms. The larger squash contained 89.10% of water in the flesh; 86.88% in the rind, and 76.71% in the seeds, &c. The smaller contained 90.20% water in the flesh; 84.42% in the rind; and 67.98% in the seeds, &c. Hence the mean percentage of water was 89.65 in the flesh, 85.65 in the rind, and 72.85 in the inside matter.

The Marrow Squash is figured in the "New England Farmer," 1834, **13.** 121. For a description of its introduction to the vicinity of Boston, see "New England Farmer," 1859, **11.** 51.

As compared with the pumpkins, the flesh of the marrow squash was rich in carbohydrates, and the same remark is true of the other kinds of squashes, notably of the Hubbard.

The composition of the sample analyzed was as follows: —

Marrow Squash.	Flesh.	Rind.	Seeds, &c.
Water	89.65%	85 65%	72.35%
Ash (free from C and CO_2) .	0.73	1.49	1.70
Albuminoids.	0.96	2.81	5.75
Carbohydrates (including fat)	7.47	7.19	15.72
Cellulose (free from ash) . .	1.19	2.86	4.48
	100.00	100.00	100.00

* Compare, for example, "New England Farmer," 1860, **12.** pp. 81, 159. See also Gasparin, "Cours d'Agriculture," 8ᵐᵉ édition, **4.** 184. According to

— Dry organic matter . . .	9.62	12.86	25.95
Fat (ether extract) . . .	0.34	0.76	7.75
Nitrogen	0.15	0.45	0.92
Crude ash	0.77	1.50	1.71

The Hubbard Squashes weighed 5 kil. and 3½ kil. They were 9×11 and 8×9 inches in diameter respectively, and their seeds, &c., weighed 355 and 350 grms. The larger squash contained 87.87 % of water in the flesh; 80.78 % in the rind; and 64.99 % in the seeds &c.: while the other contained 82.68 % of water in the flesh; 77.23 % in the rind, and 68.45 % in the seeds and stringy matter. The mean percentage of water was 85.28 in the flesh, 79.01 in the rind, and 66.72 % in the inside matter.

The Hubbard Squash is figured and described in the "New England Farmer," 1859, **11.** 113, and 1863, **15.** 209; also in Burr's "Field and Garden Vegetables," p. 218. It is supposed to be of foreign origin.

· The analyses gave the following results. It will be noticed that these results accord very well with the popular impression that the flesh of the Hubbard squash is drier and sweeter than that of other squashes. The percentage of carbohydrates (including sugar and the like) and of dry organic matter are exceedingly large; while the percentage of water is

Hubbard Squash.	Flesh.	Rind	Seeds, &c.
Water	85.28 %	79.01 %	66.72 %
Ash (free from C and CO_2)	0.91	1.13	1.64
Albuminoids	0.69	2 75	6.07
Carbohydrates (including fat)	12.13	13.22	19.33
Cellulose (free from ash) . .	0.99	3.89	6.24
	100.00	100.00	100.00
Dry organic matter . . .	13.81	19.86	31.64
Fat (ether extract) . . .	0.15	0.80	7.56
Nitrogen	0.11	0.44	0.97
Crude ash	0.93	1.17	1.68

less than in either of the other squashes examined. The proportion which obtains between the albuminoid matters and the carbohydrates in the flesh of the Hubbard squash (1 : 18½) is nearly the same as that given by Wolff for the sugar beet, and very unlike the proportion found in the flesh of the pumpkins (1 : 5) and other squashes (1 : 7.7 in the marrow, and 1 : 7.3 in the crook-neck).

The Crooked-necked Squashes weighed about 5 kil. each, and contained 89.33 % of water in the flesh, 81.35 % in the rind, and 83.32 % in the

Werner, in his "Handbuch des Futterbaues," Berlin, 1875, p. 725, the same impression, that pumpkin seeds diminish the flow of milk, has been expressed in South Germany ; and it has been recommended there, also, that the seeds should be removed on this account.

seeds and stringy matter. For figures and description of this squash, see
"New England Farmer," 1863, **15**. 209; and Burr, F., "Field and
Garden Vegetables of America," Boston 1863, pp. 214, 220.

The following results were obtained by analysis. The crook-necked
squash has, at times, been recommended for feeding animals, and it has
been urged * "that it contains more nutriment than the pumpkin, in pro-
portion to its size." The analysis shows' that this notion is true in
respect to the carbohydrates, but that it is false with regard to the much
more important constituents, albuminoids and fat. There can, therefore,
be little doubt that, formerly at least, the crook-necked squash was infe-
rior to the pumpkin as fodder; for, before the introduction of abundant
supplies of shorts and cotton-seed meal, it was no easy matter for the
farmer to prepare rations which should contain a proper proportion of
albuminoid matters. Carbohydrates, on the contrary, he had ready at
hand in the form of apples and potatoes.

Crook-neck Squash.	Flesh.	Rind.	Seeds, &c.
Water	89.33%	81.35%	83.32%
Ash (free from C and CO_2) .	0.53	1.02	0.83
Albuminoids	1.11	2.94	3.99
Carbohydrates (including fat)	8.08	11.87	9.81
Cellulose (free from ash) .	0.95	2.82	2.05
	100 00	100.00	100.00
Dry organic matter . . .	10.14	17.63	15.85
Fat (ether extract) . . .	0.04	0.59	3 61
Nitrogen	0.18	0.47	0 64
Crude Ash	0.62	1.04	0.84

With regard to the following foreign analyses, I am not certain whether
the vegetable examined should not be classed with squashes rather than
with the field pumpkins that are grown to feed cattle. It is to be noticed,
in any event, that the figures are not directly comparable with those just
now given; since, with a single exception, they refer to mixtures of flesh
and rind, or of flesh, rind, and seeds. Possibly, both the analyses may
refer to one and the same variety of the vegetable, which is described by
one observer (Dahlen) as "the oblong yellow table pumpkin (*Speisekür-
bis*)," and by the other (Wandesleben) as "a long yellow pumpkin of
less repulsive flavor than the other kinds of pumpkins."

Dahlen's † specimen, obtained at the beginning of October, weighed
nearly 2 kil. (2950 grms.); the seeds (about 200 grms.) were removed
before proceeding with the analysis, which gave the following results : —

* Compare Harris in Burr's "Field and Garden Vegetables," Boston, 1863,
p. 228.

† "Landwirthschaftliche Jahrbücher," von Nathusius & Thiel, Berlin, 1875,
p. 680.

Flesh and Rind together.	Fresh.	Dry.
Water	88.55%	——
Ash (free from C and CO_2)	0.54	4.71%
Albuminoids	1.36	11.87
Carbohydrates (including fat)	8.05	70.34
Cellulose	1.50	13.08
	100.00	100.00
Dry organic matter	10.91	——
Fat	0.08	0.71
Nitrogen	0.22	1.89
Phosphoric acid	0.09	0.77

It will be noticed that the ratio of albuminoids to carbohydrates in this case (1: 5.93) is very different from that of the foreign analyses of pumpkins previously cited on p. 85. Wandesleben * found 90.6% of water in the fresh vegetable. When dried at 100° C., the entire fruit contained 2.3% of nitrogen; the seeds 3.64% of nitrogen; and the rest of the fruit, excluding seeds, 2.14% of nitrogen; which would correspond with 14.38% of albuminoids in the entire fruit, and 22.75% and 13.38% respectively in the seeds and in the mixed flesh and rind; Dried at 100° C., the entire fruit gave 4.89% of crude or 4.41% of pure ashes, and 5.1% of fat; and the dry seeds gave 34.5% of fat. The percentage composition of the crude ashes from the entire fruit was as follows: —

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	CO_2	NaCl
17.54	18.68 (?)	6.97	3.03	2.34	29.57	2.13	6.61	9.98	0.64

Dahlen, as cited above, remarks that the ashes of his specimen were almost absolutely free from soda, and that they gave a pure potash coloration when tested in a flame. Dahlen's ash (pure, from mixed flesh and rind) contained 15% of phosphoric acid. Dahlen reports, furthermore, that his specimen contained, when dried, 14.54% of glucose (fruit sugar), which in the analysis, as above given, is of course included among the carbohydrates. According to Burr,† it was the practice in this country during the war of the revolution, when the excessively high prices of foreign sugars and molasses prevented their general use, to reduce by evaporation the liquor in which pumpkins had been cooked, and to use the sirup thus obtained as a substitute for molasses.

For the sake of comparison, the results of the analyses made in this laboratory have been re-arranged in the following table, which refers to the dry matter of the vegetables, such as is left when the natural water is expelled.

It may be said in general that the analyses of pumpkins accord very well with the ordinary opinion of our farmers as to the merits of

* Liebig & Kopp's Jahresbericht der Chemie, 1853, 6. 566.

† "Field and Garden Vegetables of America," Boston, 1863, p. 202.

THE DRY SUBSTANCE OF PUMPKINS AND SQUASHES.

After moisture had been expelled, by drying at 110° C., the *dry substances* enumerated below contained per cent of:	Ash, free from C & CO_2.	Albuminoids.	Carbohydrates, including Fat.	Cellulose.	Fat.	Nitrogen.	The per cent of dry substance, in the undried fodder, was:
Flesh of Pumpkin. No. I.	9.31	11.50	64.55	14.64	1.34	1.84	7 59
Flesh of Pumpkin. No. II.	11.61	13.75	58.76	15.88	2.52	2.20	5.43
Flesh of Pump. Mean of two	10.46	12.63	61.65	15.26	1.93	2.02	6,51
Flesh of Marrow Squash .	7.07	9.32	72.09	11 52	3.29	1.49	10.85
Flesh of Hubbard Squash.	6.17	4.52	82.56	6.75	0.99	0.72	14 72
Flesh of Crook-Neck Squash	4.94	10 37	75.82	8.87	0 38	1.66	10.67
Rind of Pumpkin. No. I. .	9.64	18.65	46.53	25.18	3.12	2.98	15.56
Rind of Pumpkin. No. II.	10.25	21.94	43.06	24.75	4.11	3.51	11.99
Rind of Pumpkin. Mean of the two	9.95	20.30	44.78	24.97	3.62	3.25	13.78
Rind of Marrow Squash . .	10.35	19 61	50.11	19.93	5.33	3.14	14.35
Rind of Hubbard Squash .	5 36	13.11	63 00	18 53	3.83	2.10	20.99
Rind of Crook-Neck Squash	5.49	15.74	63.63	15.14	3.15	2.52	18.65
Seeds and Stringy Matter of Pumpkin. No. I. . .	6.88	26.26	51 32	15.54	29.63	4.20	24.06
Seeds and Stringy Matter of Pumpkin. No. II. .	6.14	25.56	49.77	18.53	30.21	4.09	22.21
Seeds and Stringy Matter of Pumpkin. Mean of two.	6.51	25.91	50.54	17.04	29.92	4 15	23.14
Seeds and Stringy Matter of Marrow Squash . .	6.14	20.79	56.85	16.22	28.04	3 33	27.65
Seeds and Stringy Matter of Hubbard Squash . .	4.92	18.22	58.12	18.74	22.72	2.92	33.28
Seeds and Stringy Matter of Crook-Neck Squash .	4.93	23.89	58.98	12.20	21.54	3 82	16 78

this vegetable as a field crop. Pumpkins are, doubtless, somewhat more nutritious, weight for weight, than turnips, and under the conditions of farming which obtain in New England, they are more easily grown than turnips. It would appear indeed, from the statements of European writers, that there is little to choose between turnips and pumpkins as to the number of tons of each that may be obtained per acre, when the land is in fit condition and is devoted solely to one or

the other crop ; but, in this country, pumpkins are commonly grown in
conjunction with maize, as an interpolated crop, which receives no
special care or attention other than what it may get incidentally from
the cultivation of the corn.   The common practice is to put in one or
two pumpkin seeds here and there, when the corn is sown, at certain
rather wide intervals throughout the field, and to leave the vines to
take care of themselves, with perhaps an occasional effort to protect
them from the beetles which are liable to attack the young plants.
It often happens that by this careless method a ton of pumpkins to
the acre may be harvested in addition to an abundant crop of corn.

The popular impression seems to be, that the pumpkin crop is not
one specially liable to exhaust the land, and the corn crop is not sup-
posed to suffer much from the presence of the pumpkins, except that
the vines are apt to shade the corn plants, and to hinder the grain
from filling and ripening by obstructing the rays of the sun.*   The
significance of the pumpkin crop in this particular connection may be
made to appear by contrasting the chemical composition of the pump-
kin with that of the corn-stalks that are harvested at the same time.
The composition of the dry matter in maize straw, and the so-called
nitrogen ratio, are given below, after Wolff's tables, in the first line
of figures, and the composition of pumpkin flesh is given in the
second line.

Albuminoids.	Carbohydrates (including fat).	Cellulose.	Ash.	Ratio of Albuminoids to Carbohydrates.
3.49	45.35	46.51	4.65	1 : 13
12.63	61.65	15.26	10.46	1 : 4.9

Whence it appears that for feeding animals the pumpkin is in some
sense complementary to maize straw.   In other words, the pumpkin,
even if we consider its flesh alone, is competent to supply a good part
of the albuminoid matters which the cornstalks lack.   It is to be
remembered, moreover, that both the rind and the seeds of the pump-
kin are exceptionally rich in nitrogen ; and, though the value of these
refuse portions is questionable, it seems but fair to allow something
on their account in favor of the vegetable, for it is not to be supposed
that the albuminoids in pumpkin rind are wholly indigestible, or that
the seeds can never be fed to animals with advantage.   I am indebted
to my assistant, Mr. D. S. Lewis, for much labor in this research.

* Compare "New England Farmer," 1845, 24. 155.

No. 9. — *A Record of Results obtained on Analyzing the Seeds of Broom-Corn.* By F. H. STORER, Professor of Agricultural Chemistry.

THE manufacture of brooms from the spikes of that variety of *Sorghum vulgare* which is called by our farmers broom-corn, adopted in this country towards the close of the eighteenth century, apparently from the south of Europe,* soon increased to a remarkable extent, and became, long since, a very important branch of industry.

Indeed, the rapidity with which the previously insignificant occupation of making corn-brooms has been developed in this country to the rank of a great manufacturing business furnishes a noteworthy illustration both of the ingenuity and enterprise of the American people, and of a certain national mobility or readiness to accept improvements which permits such enterprise to find scope.

According to the little manual on "Broom-Corn and Brooms" by the editors of the "American Agriculturist," recently published in New York by the Orange Judd Company (1876), there are in the United States 625 manufactories, engaged in making brooms and whisks, which employ 5,206 hands. The amount of capital invested in the business is estimated at a little more than $2,000,000. The value of brooms manufactured is $6,622,285 and the amount annually paid for the manufactured brush is $3,672,837. Very little manufactured brush is exported from the country, an insignificant amount being sent to Cuba

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* They make brushes and brooms of its (*Sorghum vulgare*) stalks in Italy, which Ray observed in the shops at Venice, and which are sent to this country (England). Loudon, "Encyclopædia of Agriculture," p. 833, § 5180. So, too, in Loudon's "Encyclopædia of Plants," p. 860, note 2131, it is stated that brooms are made of the spikes of *sorghum vulgare*, which are also sent to England from Italy for the same purpose.

For a detailed description, with figures, of the broom corn, and other varieties of *sorghum* (besides other plants), that are cultivated in Italy for the manufacture of brooms and brushes, see Heuzé, G., "L'Agriculture de l'Italie Septentrionale," Paris, 1864, p. 859. According to Heuzé (p. 860), broom-corn was introduced into Europe from the East Indies in the seventeenth century. He remarks that the seeds are used in Italy for feeding cattle and poultry, and (p. 366), that France imports a certain quantity of the brush from Italy every year. According to V. Bibra, in his "Die Getreidearten und das Brod," Nürnberg, 1861, p. 846, the spikes of *sorghum vulgare* are manufactured into a variety of brooms and brushes in the East Indies and Arabia.

and South America; and the export of ready-made brooms is surprisingly small, though the amount is increasing of late years. In 1873, the value of brooms exported was $131,319; in 1874, $170,185; and in 1875, $204,696.

Of late years, the business of growing broom-corn has tended to concentrate itself in the Western States upon large farms.

"At present (1876) the centre of the culture is in Illinois, especially along the line of the Illinois Central Railroad, where not only is the aggregate area immense, but individual growers engage largely in the business, and it is not unusual to find from 300 to 700 acres in this crop belonging to one man." . . . "Missouri and Kansas also produce a great deal of broom-corn."* But, until a comparatively recent period, the crop was cultivated in a much more general way in the New England States, as well as in New York, New Jersey, Pennsylvania, Ohio, and elsewhere. That is to say, many of the farmers in the older States were accustomed to cultivate a special field or a small patch of the broom-corn plant in connection with their other crops, and to harvest it at their convenience. Often the brooms were manufactured at the farm. When this older method of cultivation prevailed, the seeds of the broom-corn plant were a noticeable feature of the crop; and they must have had at one time an appreciable influence on the agricultural practices of some parts of New England. But, upon the large Western farms of to-day and in modern practice generally, the brush is harvested so long before the seeds are ripe that the immature seeds which are scraped from the brush are little esteemed for feeding animals, and are in fact often thrown away.†

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* "Broom-Corn and Brooms. A Treatise on raising Broom-Corn," New York, Orange Judd Company, 1876, pp. 12, 40.

† "To obtain the finest brush, it must be harvested when the plant is in flower, or at most when the seed is but slightly developed. Those who follow the instructions of one writer, to harvest when the seeds begin to ripen, may get a good crop of seed, but very poor brush. Formerly, purchasers were not so exacting as to the quality of the brush, and the value of the seed was taken into account as a part of the returns for the crop; but at present one who wishes to produce the finest article allows only enough of the crop to mature to furnish seed for planting, as the diminished value of the brush is not compensated for by the value of the seed." . . . "The seed from early-cut brush hardly deserves the name, as it consists either of mere hulls with no kernel within them, or at most of hulls containing a seed from one-fourth to one-third developed. The value of such seed will depend upon the degree of maturity. That from brush harvested very early and green is worth no more as food than

This practice of early harvesting is of comparatively recent origin. Formerly the crop was commonly left standing until the seeds had become so nearly ripe that they could readily be collected and used as fodder. They were at one time quite extensively used for feeding animals in Connecticut and Massachusetts, and, as may be seen in the old volumes of agricultural journals, much questioning was indulged in as to whether the broom-corn seeds were or were not equal in value to the same bulk of oats.

A good deal of rather vague evidence has in fact been recorded at one time and another in favor of the nutritive value of sorghum seeds. It is well known that the seeds of some of the varieties of this plant are very important as human food in several hot countries. In many parts of Africa in particular, the doura or Indian millet is the staple grain, and a great deal of it is grown in the East Indies also. According to Loudon, "Encyclopædia of Agriculture," p. 833, § 5180, and "Encyclopædia of Plants," p. 860, note 2131, the flour obtained from doura in Arabia is very white, and good bread or rather cakes are made of it. The bread made from it in some parts of Italy, on the contrary, is dark and coarse. In Tuscany, it is used chiefly for feeding poultry and pigeons; sometimes for swine, kine, and horses. In India, it is much used to feed poultry, and is frequently sent to Europe for the same purpose. In the West Indies, where it is esteemed a hearty food for laborers, it is called Guinea corn.

The following citations may serve to give an idea of the opinions formerly held with regard to broom-corn seed by our farmers in some of the older States.

"Different opinions are entertained as to the value of the seed: many assert that it is superior to oats; others estimate it much lower. . It is probably worth twenty-five cents * per bushel for hogs and cattle, but is

whatever nutriment may be contained in the hulls. . . . The most successful growers say that the cutting should commence as soon as the 'blossoms' begin to fall. After the flower has been fertilized and the seed 'set,' the anthers, or male organs and male flowers, fall away, and this is called the dropping of the 'blossom.' At this time the seed has just begun to form, and is in a merely rudimentary condition, and the brush at this period is not only of the best color, but is heavier, a matter of importance in selling, and it is thought to be more durable." "Broom-Corn and Brooms," O. Judd Co., New York, 1876, pp. 18, 21. Compare U. S. Patent Reports for 1846, p. 191, and 1849–50, p. 468.

* In the same paper from which this extract is taken, the price of oats is quoted at forty-two cents per bushel in Boston market. Six years later ("New England Farmer," 1831, **10.** 167), the price of oats being quoted at forty-eight to fifty cents, the following statement occurs: "Broom-corn seed has been sold in Northampton from seventeen to twenty-five cents per bushel. The opinions of farmers vary much as to the value of this article. More than fifty thousand bushels were raised in this vicinity the past season."

of less value for horses. From twenty-five to seventy bushels of seed are obtained per acre." "N. E. Farmer," 1825, **4.** 142.

"In Morris County, New Jersey, forty bushels of seed is the average produce of an acre, which equals oats in value, as an article of food for cattle or horses." "N. E. Farmer," 1825, **4.** 252.

"In the valley of the Connecticut River, the seed is considered of about two-thirds the value of oats, and mixed with corn makes an excellent provender for the fattening either of swine or neat cattle. The return of seed is somewhat precarious; but often it is abundant, and will more than pay the whole expense of cultivation and preparing the crop for market." Henry Colman, in "N. E. Farmer," 1835, **14.** 12.

A few years later a New Jersey farmer expresses his views as follows : — "The seed makes excellent food for hogs and cattle. Its nutritious quality may easily be discovered from the fine color and taste which it imparts to butter from the cows which are fed on it. The best way to use the grain is to grind it with a portion of oats, — say about one-third of oats to two-thirds of the seed. Indeed it is so hard and flinty, that it should always be ground before feeding it to any kind of stock. Good broom-corn seed weighs about fifty pounds to the bushel. Its value compared to oats may be considered as about half as much again; so that, should the market-price of oats be, say twenty-five cents per bushel, the broom-corn seed would be worth thirty seven and a half cents." "N. E. Farmer," 1839, **18.** 131.

"A crop of seed is obtained about once in four years, and forty bushels of seed are considered a good yield. A respectable farmer in Franklin County informs me that in one instance he obtained one hundred and fifty bushels of seed to the acre. . . . The seed is sold at two-thirds the price of oats, and is ordinarily of the same weight. It sometimes weighs more than oats, and by some persons is more highly valued. It is by many esteemed good feed for the fattening of swine, when mixed with other grain. Some have used it for fattening cattle and horses, but it is not approved." Henry Colman in his Fourth Report of the Agriculture of Massachusetts, Boston, 1841, pp. 30, 32.

"Mr. Albert Hibbard of North Hadley, Mass., tells us he makes use of all the seed of his broom-corn to fatten sheep; that they are very fond of it, and will fatten better on it than on Indian corn. We have ourselves often raised the corn for the sake of the brush, but have never made much account of the seed, though hens are always fond of it. Hogs, too, will eat it, though we think it has seldom been converted to meal for hogs. Mr. Hibbard thinks the broom-corn seed more valuable for sheep than oats or any grain, pound for pound." "N. E. Farmer," 1845, **23.** 243, U. S. Patent Office Report for 1846, p. 189.

In the Mohawk valley "the seed is excellent for fattening hogs. They eat it greedily and thrive on it as well, if not better, than on Indian corn. The seed, when good, is worth in its rough state as much as oats to feed." U. S. Patent Office Report for 1846, p. 189.

"The seed of the broom-corn is excellent for fattening sheep. They are very fond of it, and will fatten on it nearly as well as on Indian corn. It is also recommended for feeding poultry, and when ground with Indian corn, rye, oats, or barley, is very profitably fed to cattle. When ground and mixed with wheat-bran it is even good for milch cows. The Shakers have frequently fed it to horses in the time of harvesting the brush; and indeed in that season of the year they seldom feed any other kind of grain. It is considered by some to be worth as much per bushel, when fully ripened and well cured, as Indian corn." Appleton's "New American Cyclopædia," New York, 1871, **3.** 741.

"Good plump seed weighs fifty pounds to the bushel, but the majority does not exceed forty pounds. It contains a great deal of nutriment, and is by some regarded as equal in value with oats to feed to sheep; ground either alone or with Indian corn, it is an excellent food for pigs and for milch cows; chickens eat it for a while as a variety, but are not fond of it long at a time. It will not, however, pay to raise seed for either of these purposes." "Broom-Corn and Brooms," O. Judd Co., New York, 1876, p. 13.

A glance at the results of the analyses given on a subsequent page will show clearly enough that several of the foregoing opinions were ill considered. The broom-corn seeds, though undoubtedly valuable as fodder when properly supplemented with other kinds of food, are not to be compared, when taken by themselves, with oats. Measure for measure, they are manifestly not fit to serve the purposes to which oats are commonly applied. The old question as to the value of broom-corn seed is, in fact, akin to another question that was current at the same time with it, to which allusion has already been made in this Bulletin, Vol. I., page 369, namely, whether a bushel of apples is equal to a bushel of potatoes for fattening animals? For both the broom-corn seed and the apples are much poorer in albuminoids than the oats and the potatoes with which they were respectively compared

The kinds of seeds examined and the results of the analyses will appear from the following statements.

I. A sample of broom-corn seed obtained in the winter of 1875–1876, at a seed store in Boston. The grain was well filled and firm, and the sample was rather better in these respects than No. II. The hulls were of a reddish color, and were not so well cleaned from filaments as those of No. II.

II. A sample of broom-corn seed obtained at a seed store in Hartford, Connecticut, in the spring of 1876. The grain was particularly clean, but not very plump, as has been said.

The results of these analyses were as follows :—

Broom-Corn Seeds.	I.	II.	Mean of the two Analyses.
Water (expelled at 110° C) .	11.20%	11.93%	11.56%
Ash (free from C and CO_2)	2.02	2.55	2.29
Albuminoids	6.97	7.56	7.27
Carbohydrates (including fat)	73.14	71.39	72.26
Cellulose (free from ash) .	6.67	6.57	6.62
	100.00	100.00	100.00
Dry organic matter . . .	86.78	85.52	86.15
Fat	3.32	3.25	3.29
Nitrogen	1.10–1.13	1.20–1.22	1.16
Crude ash	2.02	2.55	2.29

The results of the foregoing analyses are in accord with those of von Bibra,* who found in Abyssinian doura seeds 11.95% of water, 1.86% of ash, 3.90% of fat, and 1.34% of nitrogen, equal to 8.38% of albuminoids; besides 3.82% of gum, 1.46% of sugar, and 70.23% of starch and husks. The ashes of these seeds contained among other things, 20½% of potash, nearly 51% of phosphoric acid, 15% of magnesia, and 1¼% of lime. In a sample of smaller seeds from the variety of doura called Joar in Hindostance, that were grown at a height of 2,400 feet above the level of the sea and had been brought from India by H. Schlagentweit, von Bibra found 1.17% of nitrogen; *i. e.*, 7.31% of albuminoids.

Sheir & Johnston † are reported to have found 7.43% of albuminoids in Guinea corn from the West Indies.

Pierre ‡ found 1.37% of nitrogen, equal to 8.56% of albuminoids, in seeds of the Chinese sugar sorghum, and Hervé Mangon is said to have found 3.13% of oil in such seeds.

The Italian chemist Cossa, § found in seeds of the sugar-yielding sorghum; water 14.19%, ash 2.97%, nitrogen 1.57%, equal to albuminoids 9.81%, fat 3.32%, and dry organic matter 82.84%. In the seeds of the sorghum that is not sweet [doura], he found 13.21% of water, 1.95% of ash, 1.48% of nitrogen, or 9.25% of albuminoids, fat 3.13%, and dry organic matter 84.84%. In the husks of the sweet sorghum seeds, he found 12.94% of water, 81.87% organic matter, and 5.19% ash, of which 58.9% was silica. In the husks of the other variety, he found 12.08% of water, 83.12% organic matter, and 4.80% ash, of which 67.94% was silica.

It is to be noted, in this connection, that Johnston of Durham ‖ found

* In his "Die Getreidearten und das Brod," Nürnberg, 1861, p. 346.
† "Watts's Dictionary of Chemistry," 2d Supplement, p. 814.
‡ "Annales de Chimie et de Physique," 1859, 56. 44.
§ As cited in "Chemical News," 1872, 26. 289.
‖ In his "Chemistry of Common Life," New York, 1871, 1. 89.

$11\frac{1}{4}\%$ of gluten in "a beautiful white flour" from doura seeds, while in a comparative trial with buckwheat flour he got $10\frac{1}{4}\%$.

It is plain from the foregoing results, taken in connection with the relationship of the different plants, that both the doura seeds and the sugar-sorghum seeds must be wellnigh identical with those of broom-corn in respect to chemical composition, and that the one kind of seed would be equally useful with the other for feeding animals.

Since writing the foregoing statements, I notice that Dr. Vœlcker [*] has recently analyzed two different varieties of sorghum seeds [doura?], which, as he reports, can occasionally be bought in the English market at a cheap rate. His results are given in the following table: —

Vœlcker's Sorghum Seeds.	No. 1.	No. 2.	Mean of V.'s Analyses.
Water	12.32%	12.02%	12.17%
Ash	1.30	1.67	1.48
Albuminoids	7.75	7.19	7.48
Carbohydrates (including fat)	75.43	75.62	75.52
Cellulose	3.20	3.50	3.35
	100.00	100.00	100.00
Dry organic matter . . .	86.38	86.31	86 35
Fat	2.37	3.80	3.09
Nitrogen	1.24	1.15	1.20

It will be seen that these analyses are in full accord with those of broom-corn seeds given on page 99, with the exception that a somewhat smaller proportion of cellulose was found in the doura, — and a correspondingly larger amount of carbohydrates — as was naturally to be expected in the seeds of those varieties of sorghum which are cultivated expressly for the sake of the grain they bear.

It is an interesting question, well worthy of study from the commercial point of view, whether the grain-bearing sorghums may not one day become important as sources of supply for the starch-maker. It would seem to be not impossible that starch, starch-sugar, and the alcoholic products therefrom obtainable, might be manufactured from Guinea corn, grown in the countries best suited for its production, more cheaply than they can be obtained from maize, from which, at the present time, enormous quantities of all these products are made in this country.

The analyses all point to one and the same conclusion ; namely, that the proportion of nitrogenous matters in broom-corn and other sorghum seeds is small, while the proportion of carbohydrates is particularly large. From the mean of the two analyses of mature broom-corn seeds given above, it appears that the ratio of albuminoids to carbohy-

[*] "Journal of the Royal Agricultural Society of England," 1876, 12. 297.

drates is as 1 : 10 very nearly. But for oats the ratio is ordinarily as 1 : 5 : and even for maize it is usually as 1 to rather less than 8. With the exception of rice, none of the grains commonly used as human food shows so low a nitrogen ratio as the seeds of the ripe broom-corn, unless, indeed, chestnuts and acorns be classed in this category. (See Bussey Bulletin I., 376, for the composition of these nuts.)

It would seem to be plain, therefore, that, in feeding out broom-corn seed, it should be used in conjunction with those kinds of food that are much richer than it in nitrogen. Compare Bussey Bulletin I., pp. 360, 368. The following remark of Dr. Livingstone * bears upon this point. "The country [on the river Loangwa, between Lake Nyassa and the East coast of Africa] abounds in a fine, light-blue, flowering, perennial pea, which the people make use of as a relish. At present, the blossoms only are collected and boiled." . . . "Another species of pea (*Chilobé Weza*), with reddish flowers, is eaten in the same way. It is worth remarking that porridge of maize or sorghum is never offered without some pulse, beans, or bean-leaves or flowers. They seem to feel the need of it, or of pulse, which is richer in flesh-formers than the porridge."

Dr. Vœlcker, in reporting the analyses that were just now cited, very justly remarks : " Sorghum seed is rich in starch, but rather poor in nitrogenous compounds. Ground into meal, and mixed with bean or pea meal, the mixed meal will be found a good, palatable, and cheap food."

Before closing the investigation of the broom-corn seed, it seemed important to determine the chemical character of the immature seeds, which, as has been already stated on page 95, are removed from the early cut brush that is employed in the more modern practice of broom-making. To this end my friend, Mr. Charles Wright the botanist, was kind enough to collect for me at Wethersfield, Connecticut, in September, 1876, three samples of immature broom-corn seeds, from plants that had been grown from the same lot of seeds as those whose composition had been determined by analyses No. II. (see page 99).

The samples were collected at the following stages of growth: A, when the youngest anthers had not yet fallen.

* "The Last Journals of D. Livingstone in Central Africa," New York, 1875, pp. 180, 181, chap. vi. date Nov. 27.

B, when the plants were just out of flower, and the youngest anthers had all fallen.

C, collected 21 September; seeds considerably more mature than those of sample B, though still soft and unripe.

These samples of unripe seeds were dried in the air, immediately after collection, and were analyzed in the air-dried condition. But the amounts of water found in them, viz., 5.67% in A, 5.97% in B, and 7.19% in C, were very different from the proportion (11.56%) that had previously been found in the mature seeds. In order to compare the results more readily, I have consequently excluded the item water from the following statement of the analyses. The lines marked I., and II. in the following table, refer to the percentage composition of the dry substance in the mature seeds, as calculated from the analyses given on page 99. The line III. represents the mean of Nos. I. and II.

	Ash, free from C & CO₂.	Albuminoids.	Carbohydrates including fat.	Cellulose, free from ash.	Fat.	Nitrogen.	Crude ash.	Dry matter in original substance.
A	4.43	7.38	59 93	28 26	1.15	1.12–1.24	4.62	94.33
B	6.53	9 65	58.40	25 42	1.39	1 50–1.59	6.53	94.03
C	4.78	9 72	69.18	16.32	2.21	1.46–1.65	4.90	92 81
I	2.28	7 84	82 37	7.51	3.74	1 24–1.27	2.28	88.80
II . . .	2.90	8 63	81 01	7.46	3.69	1.36–1 39	2.90	88.07
III . . .	2.59	8.24	81.69	7.48	3.71	1.32	2 59	86.44

It will be seen, from these analyses, that the immature seeds contained a much larger proportion of cellulose and of ash ingredients than the seeds which had become ripe. The proportion of carbohydrates, on the contrary, increases very much, and the proportion of fat somewhat as the seeds ripen. It would seem, however, that the percentage proportion of albuminoids in the riper seeds is kept down, or perhaps even lessened, not by any removal or change in the absolute amount of these constituents at the time of ripening, but by the more rapid accumulation of carbohydrates in the seeds at this particular period of growth, whereby the relative amount of the albuminoids is made less.

The foregoing results are consistent in the main with those obtained by Arendt in his elaborate investigation of the development of the oat plant,[*]

* Arendt, "Das Wachsthum der Haferpflanze," Leipzig, 1859.

as may be seen from the following table, which exhibits the composition of the ears of oat-plants collected at the different stages of growth, which are enumerated in the foot-note.

PERCENTAGE COMPOSITION OF ANHYDROUS OAT-EARS.

Period *	Ash free from C & CO₂.	Albuminoids.	Carbohydrates, including fat.	Cellulose.	Fat.	Nitrogen.	Organic matter.
II * . . .	3.89	13.02	55 99	27.10	2.03	2.06	96.11
III . . .	3 67	11.73	64.23	20.37	3.67	1.85	96 33
IV . . .	2.84	18.02	66.33	12.81	3.72	2.85	97 16
V	2 68	19.27	66.45	11.60	2.99	3.04	97.32

As was just now seen to be the case with the broom-corn seeds, so here with the oats, the percentage proportion of cellulose in the dry matter of the ears diminishes constantly as the plants grow older. It sinks, namely, from 27% in the ears which have just formed, at the time when the stem is shooting, to about 12% at the time of complete ripeness. The percentage of carbohydrates, on the contrary, increases from 56% at the beginning to nearly 67% at the time of ripeness.

As Arendt is at pains to show, it does not appear that the cellulose in the ears changes to "carbohydrates" as the seeds ripen. On the contrary the absolute amount of cellulose in the ears remains pretty much the same from first to last, with a slight tendency to increase; but during the later stages of growth so large an amount of carbohydrates comes into the ears from the other parts of the plant that the relative proportion of cellulose is lessened. The significance of these statements may be seen from the following table which exhibits, — not the percentage composition of the ears, as above, — but the absolute amounts of the several constituents that are contained in a given number of ears harvested at the given periods. In other words this new table gives the number of grammes of cellulose, carbohydrates, ash, &c., that were contained in the ears taken from one thousand individuals of the oat plants.

* The periods at which Arendt's plants were collected for analyses were as follows, the first period being here omitted since no ears had at that time formed.

II. PERIOD. Harvested June 30, shortly before the shooting up of the stems had ceased. Panicle still half enclosed in the upper leaf sheath.

III. PERIOD. Harvested July 10, immediately after flowering.

IV. PERIOD. Harvested July 21, when beginning to ripen. Seeds tolerably well developed and susceptible of being shelled, though still soft.

V. PERIOD. Harvested July 31, when fully ripe.

THE EARS OF 1000 OAT-PLANTS CONTAINED GRAMMES OF:

At Periods.	Ash.	Albuminoids.	Carbohydrates and fat.	Cellulose.	Fat.	Organic matter.
II . . .	15 664	52 475	225.640	109.221	8.169	387.336
III . . .	25.700	82.033	449 698	142.509	25 683	674.015
IV . .	31.859	202.050	743.551	143.540	41 667	1089.141
V . . .	34 291	246.020	850.788	148.901	39.310	1245 709

It will be noticed from the previous table, that in Arendt's oat-plants, — which, as it happened, were exceptionally rich in nitrogen at all times, — the percentage proportion of albuminoids tended in the main to increase as the seeds became more mature. But with the broom-corn seeds, which are in any event much richer in carbohydrates when ripe, than oats are, a different state of things seems to have obtained; in other words, the introduction of enormous quantities of carbohydrates to the seed, at the time of ripening, appears to depress the relative proportion of the nitrogenous matters.

It is noteworthy, in this connection, that the proportion of albuminoids, as compared with that of carbohydrates, is considerably higher in the immature broom-corn seeds, than in those which are ripe. Thus in sample A, the ratio is 1:8.1; in B 1:6; in C 1:7.1; while in the ripe seeds it is 1:10 very nearly, as has been said.

In view of this circumstance, it is perhaps conceivable that for some particular cases, — in localities where foddering materials rich in nitrogen were not to be had, while those charged with carbohydrates were abundant, — the ripe seeds of broom-corn might be less valuable as fodder than the immature seeds, in spite of the large amount of cellulose which is contained in the latter. For ordinary practice, however, the excess of cellulose in the unripe seeds must be regarded as a positive disadvantage, which greatly lessens their value, and throws them into the class of rough fodders, despite the tolerably favorable relation of albuminoids to carbohydrates. It is, nevertheless, plain that the immature seeds of broom-corn are not wholly despicable as fodder. They have undoubtedly, a definite value of their own, which, though dissimilar from that of the ripe seeds, is well worthy the attention of those farmers who have ready access to the refuse that is scraped from the sorghum brush. It is emphatically true both of the ripe and the unripe seeds, that they need to be supplemented with other kinds of fodder in order that they should be used to the best advantage. According to the treatise on Broom-Corn and Brooms, to which such frequent allusion has been made in this report,

the seeds, or rather hulls, as they come from the stripping machines in which early cut brush has been scraped clean, are sometimes fed to cattle and swine, but since these green seeds soon heat and spoil they are commonly thrown upon the manure heap. Successful experiments by Professor Miles for preserving such seeds are given upon page 14 of the treatise.

He stored it in pits, as turnips or other roots are stored, putting on a layer of straw, and covering the whole with eight or ten or twelve inches of earth. Pits put up in September, were opened the following March, and were found in satisfactory condition. Where the covering was only eight inches thick, the outer portion was dry and moulded, forming a compact crust a few inches thick, but the interior of the mass was fresh and bright. A covering of twelve inches of earth preserved the seed better. A sample from the latter pit was found to be perfectly sweet, and its odor was much like that of brewers' grains.

I am indebted to my assistant, Mr. D. S. Lewis, for the analyses recorded on page 99.

No 10. — *Notes on some Common Diseases caused by Fungi.* By W. G. FARLOW, Assistant Professor of Botany in Harvard University.

(*With a Plate.*)

DURING the past year, a number of specimens of diseases produced by fungi has been examined at the botanical laboratory of the Bussey Institution, and we take the present opportunity of giving a short notice of some of the more interesting fungi examined, and of answering some of the inquiries which have been made with regard to them. With regard to some of the specimens sent, we are unfortunately unable to give any definite answer. With regard to others, further study is necessary, and they will be discussed at some future date.

In Vol. I. No. 24 of the Bussey Bulletin, we gave an account of the Black Knot, *Sphæria morbosa*, Schw., with hints as to the means of diminishing its injurious effects. As a result of that article, specimens of knots have been received from various localities, with suggestions that they must be the same thing as the Black Knot. The correctness of the statement made in the Bulletin that *Sphæria morbosa*, while very common on *Prunus Virginiana*, does not occur on *Prunus serotina* has been questioned. In no instance, however, where specimens of the knot supposed to be on *Prunus serotina* were sent, has such proved really to have been the case, but wherever there were leaves enough to make the determination of the species possible, the knots were always on *Prunus Virginiana*. During the past summer, the Black Knot was found growing on *Prunus maritimus*, the beach plum, at Menemshi Bight, Martha's Vineyard, by Mr. Vinal N. Edwards. This adds one to the list of native species susceptible to the disease. Mr. S. H. Scudder visited Black Mountain in New Hampshire, early in the season of 1876, and brought back specimens of the knot which covered the stunted forms of *Prunus Pennsylvanica* growing on the mountain. Within a few months the horticultural journals of California have mentioned the occurrence of a knot-like excrescence on the plum-trees of that State, and it would be of interest to know whether the knot is the same as that caused by *Sphæria morbosa* in the east, which has not hitherto been noticed in California.

We have not yet been able to procure any specimens of the Californian disease.

Besides the specimens in which the knots were actually or presumably caused by *Sphæria morbosa*, a large number of knots have been received whose origin is very obscure, and although our entomological friends to whom specimens were submitted were not confident that they originated in consequence of the sting of any insect, yet they certainly do not seem to have been caused by a fungus. A peculiar excrescence, bearing a very close resemblance to the true Black Knot, was sent by Professor Thomas Meehan, in the spring of 1876, who wrote that it was common on the flowering almond, *Amygdalus nana*, *var.*, near Philadelphia. The knot is black and rough on the outside, and the resemblance to branches of the plum when attacked by *Sphæria morbosa* is very striking. The interior of the knot is hard and solid, and microscopic examination does not show the presence of any fungus. On the surface, several fungi were found, but they were the sterile conditions of certain common *Sphæriaceæ* such as are usually found on exposed bark. As far as can be ascertained, the flowering almonds in the region of Boston are free from knots like that just described.

A common excrescence which is associated in the popular mind with the Black Knot of plum-trees is found on species of *Carya*, especially *Carya tomentosa*, near Boston. Some trees are covered with knots varying in size from that of a filbert to as large as a good-sized orange. They are sometimes so numerous as in winter to render the trees on which they are growing very conspicuous. They are generally attached laterally to the branches, but occasionally encircle them, and are lobed and rough on the surface, but not often of a black color. Microscopic examination fails to show any traces of a fungus in the very hard substance of the interior. A section of the younger knots usually shows traces of a bud-like structure, and the knots, which in young specimens seem to have occupied the position of a bud, look as though they were a shortened and monstrously developed axis. It would be very desirable to examine very young stages of the excrescences, but, although we have found knots of quite small size, they always seemed to be at least several months old, and we have not yet been able to recognize the disease in its earliest stages. The larger knots seem to be several years old, and apparently the disease, whatever its origin may be,

does not recur every year, but that there are intervals of inactivity; or, if we suppose that the swelling is due to the fact that certain insects sting the buds, which then take on a monstrous development, we must suppose that the insects do not make their appearance regularly every year.

Of the various excrescences on trees, classed popularly under the name of knots, it is certainly true that but comparatively few of them are the results of fungus growth. Many are known to result from the irritation caused by the stings or punctures of insects; but still there is a very large number of cases about which nothing definite is known. Of this large number of doubtful cases, it is by no means unlikely that a good share will prove on further observation to originate in the attacks of insects. Were they of fungoid origin, it is almost impossible to suppose that at least traces of the fungus causing the trouble should not be found in the knot, even when tolerably old; whereas it is well known that some of the largest knots arise from punctures of buds made by very minute dipterous insects, which are to be found only during a short time, and even then with difficulty. The whole subject of the minute anatomy and growth of swellings in plants caused by insects is of great importance, and as yet almost entirely unexplored, partly from the reason that it implies on the part of the investigator a very considerable knowledge of entomology and vegetable anatomy as well as an acquaintance with fungi. It may be asked whether some of the excrescences of plants do not arise from some spontaneous morbid action of the cells of the plant just as is the case with many tumors in the human body. That some such spontaneous morbid action occurs, is certainly true; but we have very little definite knowledge of the matter, and the experience of vegetable pathologists tends towards the belief that morbid growths in plants more frequently arise from the presence of fungi or insects than from spontaneous changes in the cells themselves.

No. 22 of the Bulletin was an article on what, from its frequent occurrence in this country, we called the American grape-vine mildew, *Peronospora viticola*. The frequency of the disease has been questioned by some, but there can be no doubt that it is very common indeed in New England, both on wild and cultivated grapes, and, inasmuch as specimens of grape leaves received from several of the Western States are also covered plentifully with the fungus, in all

probability the disease must be considered common all over the Northern States. We have never received it from California, and whether it is common in the south is still doubtful. In the article above named we referred to a second disease of the vine caused by *Uncinula spiralis*, and briefly mentioned the trouble produced in Europe by *Oidium Tuckeri*. During the past year, the *Uncinula* was more common in Eastern Massachusetts than the year before, but not, however, so common as *Peronospora viticola*. The two fungi not unfrequently were found growing together on the same leaf. In the West, however, the *Uncinula* seems to have caused more trouble than in the East, and in California it prevailed to such an extent as to have seriously injured the vines. We have received specimens from different parts of the West and from Dr. C. L. Anderson of Santa Cruz, and Mr. D. Cleveland of San Diego, California. The fungus was so common that it was frequently exhibited at agricultural societies, where it seems to have generally been called *Oidium Tuckeri*, on the supposition that it was the fungus to which that name is applied in Europe. As we have had numerous letters asking what is *Oidium Tuckeri*, and what is the mould on our grapes, we will devote a few words to a description of *Uncinula spiralis* showing wherein it differs from *Peronospora viticola* and resembles *Oidium Tuckeri*.

In midsummer and autumn, the leaves and young stalks of both our cultivated and wild grapes are covered with the white spots of *Uncinula spiralis*, which look not unlike dust. The spots are plainer on the upper than on the lower surface of the leaves, while the spots made by *Peronospora viticola* are principally on the lower surface of the leaf, and look more like frost than dust. The spots grow larger and larger until they cover the whole leaf, the young stalks, and the berries themselves. A microscopic examination made early in the season shows that the spots are composed of white mycelial threads, which branch in various directions, and are furnished at intervals with suckers by means of which the fungus is attached to the epidermis of the leaf. The diameter of the filaments is about .004 mm., and the transverse cell-walls are numerous. It will be at once seen that the mycelium of the *Uncinula* is very different from that of the *Peronospora*. In the former, it is confined to the surface of the leaves, stems, and fruit, being attached by little suckers, and frequently divided by cross partitions. In the latter, the mycelium pervades the interior of the

whole plant, and only reaches the surface through the breathing pores, which are found principally on the lower surface of the leaf, and are entirely wanting in the berries. Furthermore, in the mycelium of the *Peronospora,* cross partitions are not common. The conidia of the *Uncinula* are produced in the following manner, as represented in Fig. 2. Some of the branches of the mycelium rise up from the surface of the leaf, either obliquely or at right angles. Frequent constrictions are formed and transverse walls are produced at the constrictions, thus forming a number of cells, which are the conidial spores. The uppermost cell grows larger than the rest, and drops off. The next cell then enlarges, and drops off in the same way, and new cells are formed in the filament, so that a succession of conidial spores is formed, which ripen and drop off. The spores germinate at once by pushing out a germinating tube, generally at one end, not by producing a number of zoöspores as is the case with *Peronospora viticola.*

Late in the summer, the perithecia and asci of the fungus are formed, and they are ripe about the last of October. Fig. 1 represents the perithecia, as found in October. As seen by the naked eye, the perithecia look like small black bodies. They occur on both surfaces of the leaves, but are most easily distinguished on the smooth upper surface, inasmuch as the under surface of the leaves of most of our grapes is covered with hair, by which the perithecia are concealed. Fig. 1 shows a perithecium magnified about 550 diameters. The central mass is an opaque sac with a cellular wall, from which is given off a number of appendages which are rolled up at the end. The perithecium measures from .07 mm. to .12 mm. in diameter. The appendages are from fifteen to thirty-two in number, generally very numerous, and are from three to five times as long as the diameter of the perithecium itself. There are several cross partitions in the appendages, and they occasionally branch. At the base they are brownish yellow, but grow lighter colored at the tip, which is quite hyaline. In removing the perithecia from the leaf, the appendages are frequently broken off in the middle, so that it looks as though the fungus were a species of *Erysiphe* proper rather than of *Uncinula.* Inside the perithecia are the asci or sacs, Fig. 3, attached at the base and containing the spores. The asci vary from four to eight in number, but the more frequent number is six. The spores also vary in number, the average being six.

In short, the *Uncinula spiralis* appears in two phases. First, in the form of a white flocculent mould on the leaves, stalks, and grapes in midsummer; and, secondly, in the form of perithecia with rolled appendages later in the season. Compared with *Peronospora viticola*, it is more superficial, growing over the epidermis, but, on the other hand, is practically more dangerous, as it attacks the fruit, which is not the case with the *Peronospora*.

The European grape mould resembles very closely Fig. 2. Our figure, which was of necessity drawn from a dried specimen, represents the cells as somewhat blunt and squarish. When fresh, they were more rotund and slightly constricted at the joints, resembling even more closely the ·figures of Mohl * and Fresenius † than at present. If there is any difference between the European *Oidium Tuckeri* and the conidial form of our own *Uncinula spiralis*, it lies in the somewhat smaller size of the latter, but that could hardly be called a specific difference, since Mohl has called attention ‡ to the fact that the spores of *Oidium Tuckeri* itself are variable in size. The European grape mould was first named by Berkeley *Oidium Tuckeri* after the discoverer of the fungus; but, later, recognizing that the fungus was evidently closely related to the conidial forms of the species of *Erysiphe*, he renamed it *Erysiphe Tuckeri*. The perfect ascophorous form of *Oidium Tuckeri* is not definitely known, although some writers have associated it with other forms. Fuckel,§ for instance, considers that it ' is a conidial form of *Sphærotheca Castagnei*, a common mildew in this country and Europe, growing on the leaves of many different plants, especially on hops. His view, however, is not generally accepted.

In answer, then, to the question whether we have *Oidium Tuckeri* in this country, it should be said that we have a common fungus, *Uncinula spiralis*, whose conidial form is practically undistinguishable from *Oidium Tuckeri*. Whether or not it is precisely the same thing can never be known until European botanists have found out to what perithecial form their own grape mildew belongs; for it is a fact that some of the species of the *Perisporiaceæ*, to which order *Oidium Tuckeri* undoubtedly belongs, cannot be distinguished from one another by their

* " Bot. Zeit.," 1853. Plate XI., Fig. 7.
† " Beitr. zur Mykologie," Plate IX., Figs. 14 and 15.
‡ " Bot. Zeit." 1853.
§ " Symb. Mycolog."

conidia alone. What is called *Oidium Tuckeri* in this country is nothing more than the conidia of *Uncinula spiralis*, and we have repeatedly received specimens bearing the former name, which had been exhibited at horticultural meetings and learnedly explained, without the slightest reference to the abundant perithecia, which clearly showed the species to be *Uncinula spiralis*.

The species of *Perisporiaceæ*, to which order the grape mould just described belongs, were particularly abundant during the past summer, and several different species have been sent us with the information that they were doing great harm. From California we have received the form known as *Oidium leucoconium*, Desm., from Mr. D. Cleveland of San Diego, and Dr. H. W. Harkness of San ·Francisco. This form, which is in reality the conidia of *Sphærotheca pannosa*, Lev., was common on peaches. This is not to be confounded with the fungus which causes the curling of the leaves of peach-trees, so common in the eastern parts of the country. The latter fungus is *Taphrina (Ascomyces) deformans*, Tul.; and, although it causes a whitish color to appear on the leaves, it is readily distinguished by the curling and thickening of the leaves. From Professor Bessey of Ames, Iowa, we have also received *Sphærotheca pannosa*, which was common on cultivated raspberries, and Mr. B. D. Halsted reports that the same fungus was common on gooseberries at Lansing, Michigan. At the latter place, *Podosphæra Kunzei*, Lev., did considerable harm to the cherry-trees.

During the past summer, *Erysiphe graminis*, was very abundant, in fact more so than we have ever seen before. It attracted the attention even of persons who were not interested in fungi. It appears also to have been common in California, from which State we have received specimens collected by Dr. H. W. Harkness.

In the number of the Bulletin to which we have already referred, we expressed the view that the fungus found on orange and lemon trees in California did not derive its support directly from the bark and leaves of those trees, but rather from the remains and exudations of insects. Since then, we have received a letter from Dr. Wm. Hillebrand, who resided for a number of years at Honolulu, where the orange and lemon trees are covered with the same fungus as in California. Dr. Hillebrand writes: "It [the fungus] is not the principal factor in the mischief produced; for this is owing to the woolly plant-louse, a

middle thing between an *Aphis* and a *Coccus*, having the shape of the latter, but not its carapace, the body remaining soft and becoming clothed with a woolly covering. This animal, together with one or several species of true *Coccus*, are always found with the *Fumago*, sometimes in such numbers that there is not a leaf which does not harbor a cluster of them in its axil, where they attack and ruin the young leaf or flower-bud by their punctures. Of course, they are found on the leaves too, principally the lower face, where by their punctures they produce that exudation of gummy substance which covers the leaf often in large patches. Whether the exudation proceeds direct from the leaf or from the body of the animal, I cannot say ; but it is always after its appearance that the first black specks of the *Fumago* begin to show themselves. The *Fumago*, of itself, does little harm, at least in leaves with a glossy surface and destitute of such retaining apparatus as there is in the olive ; it, of course, impedes the respiration for the time being, but a good rainy season washes it well off and leaves the tree clean."

During the month of October, 1876, we had a good opportunity to observe how closely the fungus known as *Capnodium elongatum* followed the presence of certain insects. This fungus, which is botanically closely related to the fungus which attacks the olives and oranges of California, was abundant at Auburndale, Mass. We observed a bluish gray mass which, in the distance, seemed like the plasmodium of some species of Myxomycetes, judging from the color and the manner in which it was spread over every thing with which it came in contact, entirely regardless of its nature, whether vegetable or mineral. A closer examination showed that the alder-bushes on or near which the fungus was growing were covered with insects of a white color, covered with a woolly substance and producing a copious oily exudation. Mr. Edward Burgess, to whom specimens of the insects were sent, kindly informs us that they belong to the genus *Eriosoma.* Wherever the exudation fell, whether on other insects, on the ground, on dead sticks, ferns, or any other substance, the fungus at once made its appearance. In some cases, where the exudation dropped upon other insects, they were covered by the bluish-black fungus, while still alive. All this serves to strengthen the view, previously maintained, that the fungi of this group grow upon the exudation of insects rather than directly upon the bark and leaves of plants.

The onion smut, which has done much harm in some portions of Massachusetts and Connecticut, was examined at the botanical laboratory of the Bussey Institution. The result of the examination was published in the Annual Report of the State Board of Agriculture, and was illustrated by a plate furnished by the Society for the Promotion of Agriculture. At the time of the publication of the paper referred to, we were of the opinion that the fungus described as *Urocystis Cepulæ*, Frost, was peculiar to the United States. On further examination, we find that a fungus, described by Passerini as *Urocystis magica* occurs at Parma, Italy, on *Allium magicum*. A comparison of *U. Cepulæ* and *U. magica* shows that the two species are the same, and, although resembling *U. Colchici*, differ from that species in the size and disposition of the accessory spores. In *U. Colchici* they are broad and rather flat, fitting closely against one another, so that, when seen with the microscope, the spores proper seem to be completely surrounded by a covering of smooth accessory spores. In *U. magica*, the accessory spores are more conical and not often in close contact with one another, so that the spores when seen with the microscope have a tuberculated appearance, and the spores proper are in some places quite uncovered by the accessory spores. A careful examination of the wild species of onion growing in our country should be made by fungologists, for it seems highly probable that the fungus which does so much injury to cultivated onions will also be found on the wild species.

DESCRIPTION OF PLATE.

UNCINULA SPIRALIS, B. & C.

Fig. 1. Perithecium, with appendages, from upper surface of leaf of *Vitis cordifolia*, magnified 550 diameters.

Fig. 2. Conidia and mycelium, magnified 600 diameters.

Fig. 3. Asci and spores, magnified 600 diameters.
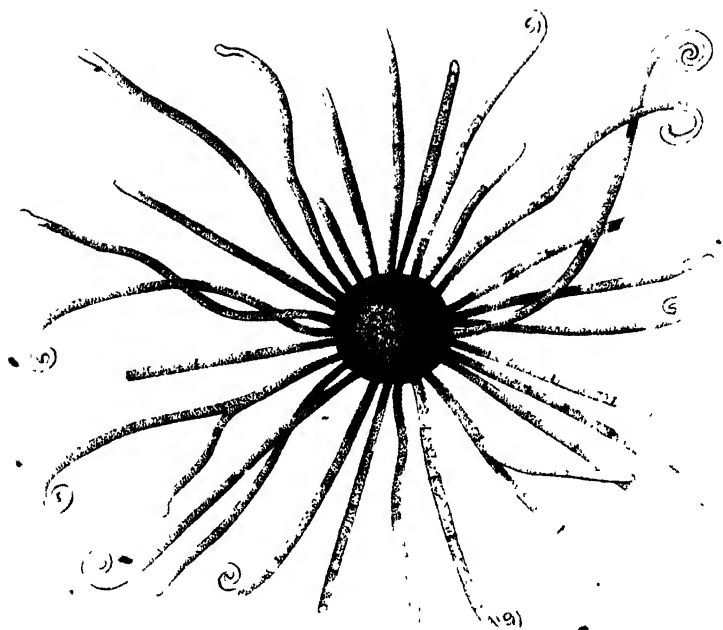
Fig 1

Fig 2

Fig 3
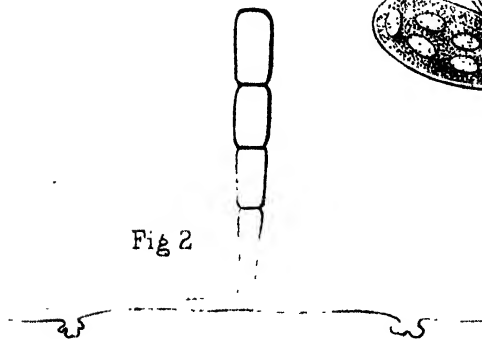
No. 11. — *A Record of Analyses of several Weeds that are occasionally used as Human Food.*   By F. H. STORER, Professor of Agricultural Chemistry.

ALTHOUGH a good deal of attention has at one time and another been given to the question of the fodder value of various weeds that occur in pastures and stubble fields, and which are known to be eaten together with grass by animals, we are still far from possessing any very definite knowledge either of the worth of such weeds or of their chemical characteristics.   Seeking to investigate this question anew, I have begun by having analyses made of several of the more promising kinds of weeds, such as are sometimes boiled as "greens" and used for human food.   For it is not unnatural to infer that plants good enough to serve this purpose may perhaps be better fitted than mere grass for feeding animals.

I have examined, among other plants, the dandelion, nettle, plantain, purslane, and lamb's-quarters or pig-weed.   In an earlier paper * will be found the analysis of the Beach Pea (*Lathyrus maritimus*) also, of which plant Drake † remarks: " In spring the vine is edible, and has been long used for food by the poorer people " [on the southeastern coast of Maine].

1. DANDELION (*Leontodon taraxacum*).   The use of dandelion leaves as a potherb in early spring is too well known in this part of the world to be insisted upon.   The plant has a large fleshy root, in which accumulations of nourishment are manifestly stored up during the later part of one season, to be used for the rapid production of leaves and flowers in the early spring of the next year.   The vigorous growth of the dandelion at a time when the ground is still so cold that many other forms of vegetation are barely starting, and the rapidity with which the leaves are reproduced when mown or fed down by pasturing cattle, are points of some importance to be considered in estimating the forage value of the plant.

As will be seen more clearly further on, the dandelion, considered as

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* Bussey Bulletin, 1. pp. 849, 351.

· † In his "Nooks and Corners of the New England Coast," New York, 1875, p. 113.

a pasture plant is somewhat analogous to white clover. That it is distinctly inferior to the clover need not be said, though this inferiority is probably somewhat less than has been commonly supposed. It will be sufficient for my present purpose to urge that, were it not for the existence of the clovers, the dandelion, and several other weeds of like habits of growth, would probably be regarded as valuable fodder plants. It is noteworthy that the dandelion is not used as greens alone. In France and Sweden, and some other parts of Europe, its leaves are blanched and eaten as a salad.

The bitter taste of dandelion leaves, especially at certain stages of their development, undoubtedly tends to make them distasteful to animals. But they are, nevertheless, often eaten, though somewhat different opinions upon this point have been expressed by good authorities. Loudon, in his "Encyclopædia of Plants," says that swine are fond of the dandelion plant, and that goats will eat it; but that sheep and cows dislike it, and that horses refuse it. From the tables of Linnæus's experiments, as reported in United States Patent Office Report for 1847, p. 519, it would appear that the dandelion is eaten by swine, horses, and goats, and sometimes by neat-cattle, but not by sheep. Sprengel,* for his part, states most explicitly that the dandelion is readily eaten by all kinds of stock, and that neat-cattle and sheep are particularly fond of it. He states that oxen may be readily fattened upon it, that cows give an abundance of excellent milk when fed with it, and that it is an advantageous fodder for sheep. He urges that it is a matter of experience in some parts of Germany, that cows fed with hay from meadows in which many dandelion plants are to be found give particularly good milk, and that it has been consequently esteemed as a meadow plant, in spite of some difficulty in drying it to hay. He expresses surprise that the plant has not been more generally cultivated as fodder. Young,† on the other hand, thought it extravagant to propose the dandelion as a plant proper for a cow pasture, and conjectured that, from having been found among good plants, it has had qualities attributed to it which do not properly belong to it. He would himself, however, have preferred dandelion for this purpose to the plantains, which were at one time esteemed.

It is not unlikely that, as is the case with so many other weeds, the

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* Erdmann's "Journal tech. und œkonom. Chemie," 1829, 5. pp. 68, 284.

† Loudon's "Encyclopædia of Agriculture," p. 888, § 5626.

dandelion plant may be eaten more readily by cattle when wilted or dried than when in the natural green condition, and the differences of opinion above recorded may be in some part due to differences as to the state of dryness of the plant in the trials made by the different observers. It is to be noted also that in Linnæus's experiments special care was taken not to offer the plants to the cattle in the spring, when many animals are ready to devour almost any green plant. In his experiments, the plan was to offer the freshly gathered plants to animals that were neither very hungry nor yet glutted with food. Sprengel, on the contrary, watched the animals in their pastures and observed what plants they ate. He noted in the pastures, also, what kinds of plants had been browsed down most closely.

The sample analyzed consisted of a large number of dandelion leaves collected May 18, 1875, in a mowing field adjoining the lawn of the Bussey Institution. The plants were in bud, but not in flower. They were cut off with a knife at the surface of the ground, as is done when the plant is gathered for table use; and the sample was, in fact, a merchantable one. The following results were obtained on analysis : —

Dandelion Leaves.	Green.	Dried at 110°.
Water	85.54%	———
Ash * (free from C & CO_2)	1.99	13.74%
Albuminoids	2.81	19.38
Carbohydrates (including fat)	8.14	56.36
Cellulose (free from ash)	1.52	10.52
	100.00	100.00
Dry organic matter	12.47	86.26
Fat (ether extract)	0.69	4.77
Nitrogen	0.44–0.46	3.02–3.17

Sprengel found 85% of water in dandelion plants gathered in May ; and Winternitz † found 8.88% of ash in plants gathered early in May, and dried at a moderate heat. He found in these ashes, among other things, 32% of potash, 6½% phosphoric acid, 16½% of lime, nearly 7% of magnesia, about 6% of silica, 8¾% of soda, and 18% of carbonic acid.

* Somewhat contaminated with sand.

† Liebig and Kopp's "Jahresbericht der Chemie," 1855, 8. 722.

II. NETTLE (*Urtica dioica.*) This plant was long ago recommended as worthy of being grown for forage,* and it has often been used as human food. According to Loudon ("Encyclopædia of Plants"), "the tops of the tender shoots are sometimes used as a potherb early in spring, and they have even been forced for that purpose." Burr ("Field and Garden Vegetables of America," 1863, p. 294) quotes from some European writer as follows: "Early in April, the nettle tops will be found to have pushed three or four inches, furnished with tender leaves. In Scotland, Poland, Holland, and Germany, these are gathered as a potherb, for soups or for dishes like spinach; and their peculiar flavor is by many much esteemed. No plant is better adapted for forcing; and, in winter or spring, it may be made to form an excellent substitute for cabbage, coleworts, or spinach. . . If the creeping roots of the plant are planted close to a flue in the vinery, they will produce excellent nettle kale or nettle spinach in January and February."

Linnæus,† in one of his journeys in Sweden, remarks as follows, under date of May 4: "Here, as happens everywhere in Sweden in the spring, nettles are gathered for greens, so long as they are tender and no more than a finger long. But when the plant has grown larger it is eaten neither by men, nor cows, goats, sheep, horses, or swine, nor by any thing except some butterflies. No medicinal or diuretic effects are observed when the young nettles are cooked and eaten as greens, but they will be perceived on boiling the older plants and drinking the juice."

The foregoing remarks, as to the refusal of cattle to eat the nettle plant, refer not only to its natural green state, but manifestly to tolerably old plants as well; for from the testimony of other writers it appears that cattle will eat the dry plant, and it is consequently to be inferred that the acrid stinging property, which is known to be due to the juice of the plant, must be lost or lessened in the process of drying.

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* By Riems in 1801, according to Fraas," Geschichte der Landbau- und Forstwissenschaft," 1865, p. 219. The dried leaves have been recommended anew, comparatively recently, by Kubelka, Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1867, **10**. 255, as an addition to the fodder of poultry and horses; and Hoffmann's "Jahresbericht," 1873–74, **16**. and **17**. p. 311, as an addition to the fodder of cows to increase the yield of milk.

† "Versuche einer Natur- Kunst- und Œconomie Historie von einigen schwedischen Provinzien," Leipzig, 1756, p. 40.

According to Langethal (" Pflanzenkunde," 1853, **3.** 38), " the sting-ing nettle supplies through its fibre a useful cloth, and the young plants afford a palatable kind of greens. The shoots can be used as fodder, also, until the beginning of June, and not be allowed to grow as a fibre plant until after that date."

According to Beckmann's " Beiträge zur Œkonomie" &c., 1783, **7.** 17, it was a practice in Mecklenburg to feed young geese upon crushed nettle plants in the morning before they were driven to the fallow fields; and again in the evening the geese received a mixture of crushed nettles and bran.

In the " New England Farmer," 1827, **5.** 186, and 1831, **9.** 206, the Bavarian Agricultural Society is credited with the report that " the nettle fattens horned cattle whether eaten green or dried; it not only fattens calves but improves their flesh; sheep which eat it bring forth healthy vigorous lambs; it promotes the laying of eggs in hens and improves the fat of pigs." The " New England Farmer," for 1828, **6.** 341, reports from a foreign paper that " the leaves are employed for feeding poultry, especially in the winter; when boiled, they promote the laying of eggs. In a fresh state, the leaves are refused by horses sheep, goats, cows, and hogs, though asses devour them eagerly; but, when *dry*, they are eaten by cows, for which they are an excellent food, increasing the quantity and improving the quality of their milk." Such fodder is thought to promote the health of the animals.

The sample analyzed was collected May 22, 1876, in a moist mow-ing field, not far from the Bussey Institution. The plants were grow-ing close to a stone-wall: they consisted of young shoots from six to eighteen inches tall. Apple-trees were in blossom at the time the plants were gathered. The entire plants, as collected, were cut into short pieces and dried upon a water-bath, and the dried material was ground to a homogeneous powder. The analyses consequently refer to a mixture of leaves and stems. The results of the analyses were as follows : —

Nettle Plant.	Green.	Dried at 110° C.
Water	82.44%	——
Ash (free from C & CO_2)	2.30	13.14%
Albuminoids	5.50	31.32
Carbohydrates (including fat)	7.80	44.39
Cellulose (free from ash)	1.96	11.15
	100.00	100.00

Dry organic matter	15.26	86.86
Fat (ether extract)	0.67	8.83
Nitrogen	0.876–0.882	5.01
Crude ash	2.58	14.68

Other analyses of the nettle plant have been published as follows : —

I. (*a* and *b*.) By Anderson, Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1864, **7.** 95. The stems amounted to 47.48% of the sample, and the leaves to 52.52%.

II. By Lenz, Hoffmann's "Jahresbericht," 1867, **10.** 255. The same analysis is credited to Moser, in Hoffmann's "Jahresbericht," for 1873–74, **16.** and **17.** (1) 311 and (2) 7.

Nettle.	Ia. Green stems.	Ib. Green leaves.	II. Air-dried leaves.	Ib. Air-dried leaves.
Water	82.06%	75.65%	11.42%	11.42% *
Ash (free from C & CO_2) .	1.66	4.34	14.03	15.79
Albuminoids	2.12	5.87	18.34	21.35
Carbohydrates (including fat)	——	——	45.56	——
Cellulose	——	——	10.65	——
			100.00	
Dry organic matter . . .	16.28	20.01	74.55	72.79
Fat	——	——	7.73	——
Nitrogen	0.34	0.92	——	3.35

The analyses show that the moderately young nettle plant is exceedingly rich in nitrogen, and that it contains comparatively little cellulose. In so far as its chemical composition is concerned, the plant manifestly has real merit as a foddering material. It will be seen for that matter that the analyses fully support the favorable reports of practical experience that were just now cited. Unless the plant has some medicinal or hurtful action that has not yet been determined, it must add decidedly to the nutritive power of the hay from those road sides, headlands, and waste places, where nettles abound, with which they are not unfrequently admixed in noticeable proportion. This remark applies, of course, with especial force to early-cut hay ; for the stalks of the nettle plant become somewhat fibrous and stringy when fully grown.

"The stalk is found to have a texture somewhat like that of hemp, and to be capable of being manufactured into cloth, ropes, and paper." Loudon " Encyclopædia of Plants."

"On being dressed in a manner similar to flax or hemp, the nettle

* Assumed from No. II.

fibre has in some parts of Europe been advantageously manufactured into cloth. This industry has been attempted in Great Britain, also; and a coarse kind of durable canvas was produced, which was considerably harder than the cloth manufactured from hemp or flax. . . From the rind, as well as the woody substance of the stalk, Dr. Schæffer has produced a very good white writing-paper." "New England Farmer," 1828, 6. 341.

"The common nettle has long been known as affording a large proportion of fibre, which has not only been made into ropes and cordage, but also into sewing thread, and beautiful white linen-like cloth of very superior quality." Lawson, cited by Burr in his "Field and Garden Vegetables of America," 1863, p. 294.

"Bast fibre was formerly separated in Europe from the common stinging nettles, *Urtica dioica* and *U. urens*, as it is from flax, and the so-called nettle cloth which was made therefrom was held in great consideration on account of its fineness. In the course of time, however, the nettle cloth has been supplanted by the finer kinds of linen, and has completely gone out of use. An attempt has recently been made to render *U. dioica*, in particular, available; but there are as yet no trustworthy reports from which to determine whether the culture of this plant offers any real advantages over that of flax." Hugo Müller's "Treatise on Cellulose," in Hoffman's "Bericht über der chemischen Industrie," Braunschweig, 1877, p. 41.

It is to be remarked, in this connection, that the circumstance of a plant's bearing some part of its cellulose in the fibrous condition suitable for making cloth need not necessarily unfit that plant for use as fodder. Much would depend upon the amount of this cellulose as compared with that of the other ingredients, as well as upon its toughness or rigidity. For an interesting statement of the successful use of unrotted flax straw for feeding neat-cattle in a time of dearth, see "New England Farmer," 1837, 15. 270. According to Loudon's "Encyclopædia of Plants," the refuse from dew-rotted flax has long been held to be an excellent food for horses and cattle; but, in the case in question, a quantity of old flax straw was simply chopped short with an axe and given to the animals by small portions. They ate it readily, and were maintained in good case by means of it. In the same sense, a Minnesota farmer has recently reported[*] his experience

* See "New York Weekly Tribune," Feb. 7, 1877, p. 7, col. 1.

in feeding out flax straw from which seed has been threshed. He
finds that cattle can be wintered perfectly well, with very little addi-
tion of other food, when permitted to have access to such straw; and
he considers a rick of good flax straw, with the chaff mixed through it,
worth more than a rick of prairie hay. His practice is to harvest the flax
tolerably ripe, and thresh it two or three days after harvesting, while the
straw is still bright and there is substance in the chaff. Since it is im-
practicable to save all the seeds, some part of the fodder value of the
straw and chaff must be credited to stray seeds that have been left in it.

This last communication led to the following correspondence. A
Nebraska farmer wrote to the " Weekly Tribune " (March 7, 1877):
" I see an item comparing flax straw to prairie hay, to the disadvan-
tage of the latter. While we know that stock will eat it with avidity,
still the idea seems to prevail that it will not do to allow cows in calf,
or mares in foal, free access to the straw, on the supposition that they
will thereby lose the fœtus they may carry. But for this notion, and
the danger of such animals finding access to flax straw, many would
use it where flax is grown, where it is now burned where threshed.
Will some of those having experience enlighten us on this sub-
ject?" In reply to this call, two Kansas farmers wrote as follows
(" Weekly Tribune," April 4, 1877) : " I would say that my experience,
which has been considerable, convinces me that flax straw mixed with
the chaff so far from being injurious to cattle or horses, is decidedly
one of the best feeds to be had in the West. Cattle like it, and will
eat it in preference to prairie hay; and, when the two are mixed, I
esteem one ton of flax straw as worth at least two tons of western
hay. I have nine cows which, during the past winter, had free access
to stacks of both flax and hay, and in each case they showed a decided
preference for the flax. Each of these cows was with calf and all
have done well. So far from casting the fœtus prematurely, they have
in four instances gone from four to five days over the time allotted.
My cattle are all looking well, having soft skins, and glossy, oily hair,
and are in every respect in better condition than on any previous
spring when deprived of this food. My conclusion is that flax straw
will not injure either cattle or horses under any circumstances, when
properly admixed with prairie or other hay, though it is well known
that the naked seed, given in excess, will effect serious damage and
premature discharge of the fœtus."

The other writer says: "I have used flax straw for feeding cows with calf all winter, and they are in good order, and in fact in better flesh than those of some of my neighbors, who fed prairie hay."

III. THE COMMON PLANTAIN (*Plantago major*) seems to be readily eaten by sheep, who are evidently much better fitted than most other animals for cropping its low spreading leaves. According to Linnæus's table as given in the U. S. Patent Office Report for 1847, p. 514, the common plantain is eaten in the green state by sheep, hogs, and goats, but not by horses or by oxen. According to the "New England Farmer," 1837, **16.** 21, swine are particularly fond of plantains, both the root and the leaf. In early spring the leaves, somewhat younger than those which were collected for analysis as described below, are sometimes boiled and eaten as greens here in New England.

For the analysis, a large number of the plants were collected May 25, 1876, from a variety of places upon the Bussey Farm, — some from upland pastures, and some from low-lying meadows. No seed-stalks had as yet made their appearance, so that the analysis refers to the leaves alone. It was noticeable that, with scarcely a single exception, numerous small holes had been eaten through the leaves by a small jumping beetle, which, as my friend Mr. S. H. Scudder informs me, is known as *Dibolia aerea*, by entomologists. As was the case with the other weeds, the great mass of leaves collected was dried upon a water bath, and the dry matter was ground to a fine homogeneous powder in order to secure a fair sample of the plant for the analysis.

The following results were obtained. It will be noticed that the plantain leaves, though less rich in albuminoids than either of the other weeds mentioned in this report, have still a composition of such character that they would seem to be not ill-suited for feeding animals.

Plantain Leaves.	Green.	Dried at 110° C.
Water	81.44%	——
Ash (free from C & CO_2)	2.16	11.64%
Albuminoids	2.65	14.29
Carbohydrates (including fat)	11.66	62.80
Cellulose (free from ash)	2.09	11.27
	100.00	100.00

Dry organic matter	16.40	88.36
Fat (ether extract)	0.47	2.53
Nitrogen	0.43—0.43	2.29
Crude ash	2.47	13.29

It is worthy of remark that this analysis differs considerably in respect to cellulose and carbohydrates from the analyses of the narrow-leaved plantain (*plantago lanceolata*), called also lance-leaved plantain, lamb's tongue, rib-grass, and ribwort, as made by several chemists. Of the following analyses A refers to an analysis of the green plant made by Vœlcker, and B to an analysis by Way of the green plant collected 28 May. Both A and B are cited from Werner's "Futterbau," 1875, p. 629.

C is an analysis by Hofmeister, cited in Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1870–72, **13.** to **15.** (3) p. 8, of plants collected from a stubble-field. His results are calculated upon the dry plant.

Lance-leaved Plantain.	A. Green.	B. Green.	C. Dried at 100° or 110°.
Water	80.79%	84.75%	——
Ash (free from C & CO_2) . . .	1.83	1.35	11.54%
Albuminoids	2.48	2.18	13.64
Carbohydrates (including fat) .	5.90	6.62	52.82
Cellulose	9.00	5.10	22.00
Dry organic matter	17.38	13.90	88.46
Fat	——	0.56	——
Ratio of albuminoids to carbo- hydrates	1:2.4	1:3	1:3.8

Sprengel found 76% of water in green leaves and stems collected in September. Way and Ogston * found 84.75% of water, and 1.32% of ash in the fresh plant, or 8.68% of ash in the dry substance.

This narrow-leaved or rib-wort plantain has often been commended as a forage plant, and it was formerly sometimes sown purposely as a pasture grass. According to Loudon's "Encyclopædia of Agriculture," "it is eaten heartily by every sort of cattle, more especially when in the cultivated state, and in particular by cows, who like it most in May, when it has great influence on the milk, as the hay has on the flesh. In Scotland, it is a useful addition to the proper grasses on lands to be pastured by sheep. Where kept well fed down by stock

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* Liebig and Kopp's "Jahresbericht," 1850, **3.** p. 668, table B.

there can be no doubt of its being a very good and nourishing pasturage plant for both cattle and sheep ; but it is by no means adapted for hay or soiling.   On dry soils it affords little herbage, and is often left untouched by cattle.   It has been made use of in some parts of Yorkshire as a summer grass.   As an article of pasturage for cattle and sheep, it is there in high esteem ; it is not, however, well eaten by horses.   As an article of hay it is held to be detrimental to the crop, retaining its sap an unusual length of time, and when fully dry falling into a small compass, or being broken into fragments and left behind on the field."

Sprengel * wrote of the narrow-leaved plantain as follows : —

" Though classed among the worst kinds of weeds by some writers, it nevertheless belongs among the plants that are worthy of cultivation, since it affords a healthy and nutritious fodder.   It is better suited for pasturage than for mowing ; and since it is greedily eaten by sheep, since it can be pastured incessantly without injury, and since it lasts for several years, we have in it a plant particularly well fitted for the improvement of sheep-walks. . . . It begins to vegetate very early in the spring, and, when continually pastured, does not cease to grow until checked by the autumn frosts. . . . One evidence that it belongs among the best pasture plants is to be found in the fact that it is commonly found most abundantly in those pastures which are most highly esteemed for fattening animals and for producing milk."

The Rev. C. W. Howard,† of Kingston, Georgia, in his essay on the grasses of the south, commends the narrow-leaved plantain in the following terms : —

" It will live at the South on the poorest land, but is valuable only on good land.   If not grazed during the summer, it will afford a considerable amount of winter food.   Cattle, horses, and sheep eat it in winter with avidity.   Hogs are not fond of it.   It is a useful constituent of a winter pasture at the south, and its growth is therefore encouraged on this farm."

The table of Linnæus, in " U. S. Patent Office Report," 1847, 514, reports that the green plant is eaten by sheep, horses, and goats, but not by oxen ; upon which Loudon in his " Encyclopædia of Plants," comments as follows : " Haller attributes the richness of the milk in

* Erdmann's " Journal für techn. und œkon. Chemie," 1829, 5. 143.
† " U. S. Patent Office Report," 1860, p. 280.

Alpine dairies to this plant (and another); but Linnæus says, cows refuse it, and this every shepherd knows to be the case as far as respects the flower stalks. Zappa, of Milan, and Arthur Young, speak in high terms of it; but the general feeling and practice of scientific agriculturists is against it, and it is now seldom sown."

Perhaps the last words that have been written upon the subject are those of Werner,[*] who urges that the advantages of the plant are that it yields early pasturage, lasts for a long time, and bears continual cropping; that it is readily eaten by cattle, and that its deep roots enable it to withstand drought, to grow upon poor land, and to obtain its nourishment without exhausting the upper layers of soil. In view of these circumstances, it may not be amiss to encourage the growth of the plant upon poor, sandy pastures. But for fertile fields, on the other hand, it is disadvantageous; since its low-lying leaves occupy an amount of space altogether disproportionate to the value of the plant, and tend to crowd out or cripple the neighboring vegetation. In a mowing field, the total amount of forage yielded by the plantain is very small as compared with the yield of a similar area occupied with clover plants or good grasses.

PURSLANE (*Portulaca oleracea*) was formerly frequently cultivated as a potherb. It was used as a salad also, and for garnishing and pickling, but it has been superseded by better plants and is now little used. Compare Loudon's " Encyclopædia of Plants." The fondness of swine for this plant is well known, and the analysis goes to show that the dry matter in it must be a highly nutritious food. The sample was collected July 14, 1876, from a garden plot on the Plain-field of the Bussey Institution. The plants were in bud, but not yet in blossom.

Purslane.	Green.	Dried at 110°C.
Water	92.61%	——
Ash (free from C & CO_2)	1.56	21.06%
Albuminoids	2.24	30.25
Carbohydrates (including fat)	2.56	34.73
Cellulose (free from ash)	1.03	13.96
	100.00	100.00
Dry organic matter	5.83	78.94
Fat (ether extract)	0.40	5.35
Nitrogen	0.357—0.359	4.83— 4.86
Crude ash	1.93—1.94	26.08—26.26

[*] In his " Handbuch des Futterbaues," Berlin, 1875, pp. 628–630.

It should be stated that the determination of albuminoids (*i.e.* of nitrogen) in this particular plant, as given above, is not quite correct; since the plants contained a rather large amount of nitrate of potash, the presence of which, as is well known, tends to vitiate the estimation of nitrogen by the soda-lime process, which was used in this instance. The purslane contained so much nitre that the dried powder of it burned like touch-paper, on being ignited for the estimation of the ash. So, too, on percolating a quantity of the dried plant with water, and testing the acidulated filtrate by boiling with metallic cadmium and adding iodo-zinc starch solution, a strong reaction for nitric acid was immediately obtained.

Pig-weed or Lamb's-Quarters (*Chenopodium album*). A sample collected upon the Plain-field of the Bussey Institution, Aug. 1, 1876. The plants, which were of medium size, were in blossom when gathered.

Pig-weed.	Green.	Air Dried.	Dried at 110° C.
Water	80.80%	9.81%	——
Ash (free from C & CO_2) . . .	3.02	14.21	15.76%
Albuminoids	3.94	18.59	20.61
Carbohydrates (including fat) .	9.69	45.44	50.38
Cellulose (free from ash) . . .	2.55	11.95	13.25
	100.00	100.00	100.00
Dry organic matter	16.18	75.98	84.24
Fat (ether extract)	0.76	3.55	3.94
Nitrogen	0.63—0.63	2.97—2.98	3.30
Crude Ash	3.82	17.95	19.90

Luyken, as cited in Wolff's tables, found in the plant dried at 100° 13.19% of crude ash and 10.36% of ash free from C and CO_2, and the latter contained 50% of potash, 8% of phosphoric acid, 28¼% of lime, 7% of magnesia, &c.

The young plant is still sometimes boiled and eaten as greens, and appears to have been frequently used in this way formerly. The analysis shows that it is rich in foddering materials.

Perhaps the best way of conveying an idea of the probable fodder value of the foregoing plants will be to contrast their composition with that of various well-known vegetables, as may readily be done by means of the following table, the first part of which, relating to turnip tops, &c., has been copied from the tables of Wolff, and of Dietrich and

Kœnig. It will be seen that most of these weeds are particularly rich in nitrogenized matters, while the amount of cellulose contained in them is by no means large. There is a great deal of water in the weeds, but no more than there is in most of the other succulent vegetables with which the weeds are here contrasted. Whether we take

Name of the Fodder.	Per cent of Water.	Ash, free from C & CO₂.	Albuminolds.	Carbohydrates, including fat.	Cellulose.	Ratio of Albumin. to Carbohydrates.	Dry Organic matter.	Fat.
Turnip leaves	85.00	1 80	2.80	9.00	1.40	1:3.2	13.20	0 80
Rape,* mowed in blossom	85.39	1.80	2.93	5.46	4.42	1:1 9	12.81	1.10
Carrot leaves.	79.35	3.45	3.51	10.46	3 23	1:3.0	17.20	1.00
Beet (Mangolds) leaves .	90.50	1.80	1.90	4.50	1 30	1:2.4	7.70	0.50
Cabbage	89.00	1 20	1.50	6 30	2.00	1:4 2	9 80	0 40
Ruta-baga roots . . .	88.41	0 78	1.15	8.56	1.10	1:7.4	10 81	0 10
Buckwheat, mown green	85.86	1.24	2.05	6.49	4.36	1:3.2	12.90	0.66
Red Clover (before flowering)	82.83	1.49	3.36	8.21	4.11	1:2.4	15.68	0.63
White Clover (in full flower)	80.50	2.00	3.50	8.00	6 00	1:2.3	17.50	0.80
Pasture Grass	78.35	2.07	5.24	10 62	3.72	1:2.0	19 58	0.96
Fodder Corn† (cut tolerably young)	85 01	1.01	1.85	7.74	4.39	1:4.2	13.98	0.56
Dandelion	85.54	1.99	2.81	8.14	1.52	1:2 9	12.47	0.69
Nettle	82 44	2 30	5.50	7.80	1.96	1:1.4	15.26	0 67
Plantain	81.44	2.16	2.65	11.66	2.09	1:4.4	16 40	0.47
Purslane	92.61	1.56	2.24	2.56	1.03	1:1.1	5.83	0.40
Pig-weed	80.80	3.02	3 94	9.69	2.55	1:2.5	16.18	0.76

the dandelion or the turnip for example, there is no more than some 250 or 260 pounds of dry organic matter in a ton of the green leaves. The proportion of ash in the weeds is large in almost every instance. It has indeed long been known to be true of weeds in general, that they contain a larger proportion of ash ingredients than most cultivated

* Werner's "Handbuch des Futterbaues," p. 608.

† Compare Prof. Johnson's recent analyses of older fodder corn in "American Journal of Science," March 1877, p. 202.

plants. I am ignorant as to what influence, if any, these ash ingredients may have upon the fodder value of the weeds. It is not probable, however, that they are specially hurtful. The proportion of ash in pasture grass, it will be noticed, is not particularly small. It has indeed sometimes been urged that the saline constituents of weeds are beneficial to animals. Sprengel * held, for example, that one advantage, in using the dandelion as fodder, lay in the fact that the leaves are rich in common salt; *i.e.*, in sodium compounds.

The general conclusion to be drawn from the evidence now attainable is, that the weeds here in question really have a considerable value for feeding animals; and that, although they are unfit for cultivation because inferior to the plants now actually grown with which they would have to come into competition, they should not on that account be completely neglected or despised. It is undoubtedly true that many an American farmer will occasionally find himself so situated that it would well be worth the while for him to collect such weeds and feed them out systematically in conjunction with other kinds of food; and it is to be urged emphatically that when, as constantly happens, such weeds are collected merely for the purpose of destroying them, they should be used as fodder, in some definite and methodical way, rather than be composted, or burned, or thrown aside, as is now too much the custom almost everywhere. It is to be remembered, moreover, that any new incentive to the collecting of weeds, such as the establishment of a habit of putting them to use in that stage of development at which their fodder value is greatest, would work very surely towards clearing the land of the unwelcome intruders.

I am indebted to my assistant, Mr. D. S. Lewis, for aid in this investigation.

* Erdmann's " Journal tech. und œkon. Chemie," 1829, **5.** 284.

No. 12. — *On the Chemical Composition of Blue Joint-grass* (Calamagrostis Canadensis), *as contrasted with that of Reed Canary-grass* (Phalaris arundinacea.) By F. H. Storer, Professor of Agricultural Chemistry.

I HAVE sought to test, by way of analysis, the question whether the so-called blue joint-grass (*Calamagrostis Canadensis*), which grows not infrequently upon the better sort of wild wet meadows in this vicinity, is deserving of the high esteem in which it is commonly held by our farmers. At the same time, and for the sake of comparison, I have had new analyses made of the reed canary-grass or ribbon grass (*Phalaris arundinacea*), a species which might readily be made to yield abundant crops of hay in many wet places, but which is held in little repute hereabouts.

The character of the specimens examined will appear from the following statements : —

I. Blue joint-grass (*Calamagrostis Canadensis*) gathered June 30, 1876, from a boggy meadow on the Bussey Farm. The stalks were 4 to $4\frac{1}{2}$ feet high. Each stalk was completely headed out and in blossom. The meadow was very wet when the specimen was gathered. Most of the grass was dried in the air, in a shady place for the analysis. A small sample of the green grass dried at 105° to 110° C. lost only 46.53% of moisture, an amount which is so very small, as compared with the proportion of water found in other grasses, that I am anxious to repeat the experiment to test its accuracy. It is not wholly improbable, however, that this estimation of water is correct, for the blue joint-grass has a somewhat peculiar habit of growth. The amount of stalks or straw, namely, in this grass, is disproportionately large as compared with the number and size of the leaves. To this cause, no doubt must be attributed the general chemical character of the grass, as shown by the analyses below. The grass shoots up so tall and slender that it would not be strange if the long straw-like stalks should contain comparatively little moisture or be poor in nutritive matters. But the stalks, being in excess of the leaves, determine in good part the character of the whole plant.*

* A sample of the grass gathered nearly a year later than the one above mentioned in the same meadow, viz., on June 20, 1877, contained 59.88% of water. This sample was not quite in blossom, though almost. It will be noticed that, in this case, the proportion of water, though larger than in the sample of the previous year, is still much smaller-than has usually been found in other kinds of grasses.

II. A specimen of blue joint-grass gathered July 7, 1876, upon the D. Lewis farm at Rochester, Mass., by my assistant Mr. D. S. Lewis. The stalks were of uniform length, four feet, and the plants were in blossom. The meadow from which this sample was collected was very dry, no rain having fallen in the vicinity for six weeks or more. The specimen was dried in the shade and analyzed as hay. No attempt was made in this case to determine the amount of moisture in the green grass, since it was collected at a distance from the laboratory.

III. Reed Canary-Grass (*Phalaris arundinacea*) gathered June 13, 1876, on the banks of Stony Brook, near Boylston Station, on the Boston and Providence Railroad, from low ground that was shaded a considerable part of the day, perhaps a quarter of the day. The sample was not particularly uniform as to the size of the stalks, some of them being $4\frac{1}{2}$ feet long with buds fully developed, though no blossoms; while other stalks were not more than two feet long with buds just appearing. The sample was covered with dew when gathered, and the estimation of moisture (74.69%), as recorded below, relates to plants from which the dew had just dried off. The larger part of the sample was made into hay in a shady place and analyzed as such.

IV. Reed Canary-Grass (*Phalaris arundinacea*) gathered June 15, 1876, from the edge of a running brook on the Bussey Farm, nearly two miles distant from the locality where No. III. was collected. The stalks were of uniform length, $3\frac{1}{2}$ feet, and the buds upon them were fully developed, but not yet opened. The specimen was dried in the air in a shady place, for analysis. An estimation of moisture in the grass, as gathered, gave 78.83%.

The results of the analyses were as follows : —

Hay of blue Joint-Grass.	I.	II.	Mean of the two Analyses.
Water	9.77%	9.22%	9.50%
Ash (free from C and CO_2)	4.19	4.30	4.24
Albuminoids	6.72	5.59	6.16
Carbohydrates (including fat)	39.32	41.42	40.37
Cellulose (free from ash) .	40.00	39.47	39.73
	100.00	100.00	100.00
Dry organic matter . . .	85.04	86.48	85.76
Fat (ether extract) . . .	2.14	2.06	2.10
Nitrogen	1.07—1.08	0.87—0.92	0 99
Crude ash	4.19	4.30	4.25
Ratio of albuminoids to carbohydrates	1 : 5.9	1 : 7.4	1 : 6.6

The close agreement of these analyses of samples collected from very different localities is to be noted, as well as the fact that the

results of the analyses do not accord with the popular estimation in
which this variety of grass is held.   It seems probable that our farmers
have been misled by the fact that cattle eat both the joint-grass itself
and the hay which is made from it much more readily than they will
eat most of the other bog grasses.   But a test like this, based solely
upon the palatableness of a plant, is manifestly of little or no value as a
means of determining the amount of nutritive matter in the plant ; and
the analyses make it probable that in the present instance cattle relish
the joint-grass more than they do the rougher grasses with which it
comes into competition, merely because of its comparatively delicate
structure and its tenderness, so to speak.   They are repelled, on the
other hand, from the various species of Carex * which grow upon our
wet meadows as well as from the reed canary-grass, to be considered
directly, because of the harsh texture of these plants, their roughness
and stiffness, and the sharp cutting edges which many of them possess.

I am ignorant as to the average amount of hay that could be got
per acre from wet land mainly devoted to the joint-grass.   No doubt
it would be large.   But there is every reason to suppose that at the
best it would be decidedly less than could readily be got from the reed
canary-grass, as stated below ; and, in view of the chemical composi-
tion and the easy culture of the latter, it would seem to be much
better worth the attention of our farmers than the blue joint-grass.

The composition of the reed canary-grass will appear from the fol-
lowing analyses.   The reader will have noticed from the descriptions
already given that this grass was in bud when examined, but not yet
in flower.

Hay of Reed Canary-Grass.	III.	IV.	Mean of the two Analyses.
Water	9.56%	10.11%	9 84%
Ash (free from C and CO_2) .	5.99	8.18	7.08
Albuminoids	10.00	11.09	10.54
Carbohydrates (including fat)	41.55	37 42	39.49
Cellulose (free from ash) .	32.90	33.20	33.05
	100.00	100.00	100.00
Dry organic matter . . .	84.45	81.71	83.08
Fat† (ether extract) . . .	2.69	3.36	3.03
Nitrogen	1.60	1.75—1.80	1.72
Crude ash	5.99 & 6.13	8.18 & 8.33	7.16

* For analyses of *Carex stricta* see " Bussey Bulletin," I. 345.
† Together with much green coloring matter.

Water in the green grass	74.69	78.83	76.76
Ratio of albuminoids to carbohydrates	1:4.2	1:3.4	1:3.7

Directly contrary to the experience with blue joint-grass as just now stated, the results of these analyses of reed canary-grass are surprisingly better than was expected. They indicate, in short, the presence of very considerable amounts of nutritive matters. In the face of these analyses, there can hardly be room to doubt that this grass has real merit, and that it needs only to be properly managed in order that it may commend itself. There is really no cause for surprise that a grass growing like my samples at the edge of running water, upon land that was not overwet, should elaborate an abundance of the constituents that are useful food for animals: the conditions of growth were, in fact, not unlike those which obtain upon the irrigated meadows of Europe. It appears, indeed, on consulting foreign authorities,* that the reed canary-grass is held in considerable estimation abroad. As a substitute for our wild bog grasses, it could doubtless be grown with advantage in numberless localities in this country ; for it yields an enormous burden of hay, is easily planted, and when once established in a fit place, does not readily die out. Though not merchantable, perhaps, in the usual sense of the word, the hay from this grass, when cut young enough, would undoubtedly be valuable for feeding stock at the farm.

It appears,† curiously enough, that an attempt was made nearly half a century ago to introduce the cultivation of this grass into American practice, and the abundant beds of it at the localities where my specimens were collected seem to show that the effort was not wholly unsuccessful in this vicinity. But it is plain, upon the face of the matter, that this grass can only then be useful, when managed intelligently, and by persons who have a clear appreciation of the character of the grass at the several stages of its development. For that matter, the chemical evidence given above does but re-enforce and justify the testimony offered by the mechanical structure of the grass, to the effect that it should be mown when very young, — that is to say, three times every year, — in order to be a really useful fodder. The

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* See, for example, Langethal's "Lehrbuch der Pflanzenkunde," Jena, 1855, 1. 72; and the authors cited on pages 134, 185.

† See "New England Farmer," 1834, 13. pp. 41, 129, and 1835, 14. pp. 50, 125.

coarse, rough, strawy character of its ripe stems and chaffy heads shows clearly enough that the fodder value of the plant is peculiarly liable to deteriorate as it grows older. The merit of the analysis consists merely in showing that there is an abundance of nutritive matters actually present. It is the farmer's business so to manage the crop that these nutritive matters may be put to profitable use.

The statements of standard European authorities, to which reference was just now made, leave little more to be said in respect to this grass, except that it would seem to be specially well suited to a thinly settled country like our own, where the cheapness and poverty of the land and the high cost of labor tend to prevent high farming, and to encourage the growth of such crops as can be obtained at little cost of labor and dung. Gasparin,* for example, says of it: " This plant does not really prosper unless its roots are in contact with water. It will grow indeed on dry land, but less vigorously. Loam that is rather sandy than clayey, upon the borders of brooks or bodies of water, suits it best. It should be mown before flowering, lest the hay should become too hard. Although of coarse appearance, the forage is readily eaten by cattle, if it has been cut early enough. The plant is abundant on the plains of Lombardy. The hay of normal quality contains 1.49% of nitrogen " (equal to 9.31% of albuminoids).

In the Duke of Bedford's experiments upon the produce of different grasses, it appeared that this grass, grown upon a black sandy loam and cut at the time of flowering, yielded at the rate of 12,250 lbs. of hay to the acre; when grown upon a strong, tenacious clay, the yield was at the rate of 17,000 lbs. to the acre. It should be said that the experiments by which these results were obtained were made in the small way, and under conditions particularly favorable for the growth of the grass. It may or may not be true that they indicate the largest yield of hay that could possibly be obtained from this grass. But it is to be noted that, in actual farm practice, amounts of hay much smaller than those just stated would be considered very large crops.

According to Linnæus,† the green grass is eaten by horses, oxen, sheep, and goats, but not by swine. He remarks that horned cattle are fond of it, and that the peasants in the south of Sweden mow two

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* In his " Cours d'Agriculture," 3ᵐᵉ édition, 4. 887.
† As cited in " U. S. Patent Office Report," 1847, pp. 518, 521.

crops a year for their use. Werner,[*] in remarking upon the fact that the grass succeeds best in meadows that are occasionally overflowed by good nourishing water, calls attention to the circumstance that the grass really takes very little from the soil under these conditions, since it is supported for the most part, if not entirely, by matters taken from the water. According to him the grass can bear shade, and may be grown with advantage not only beside running water, but in mere bogs or swampy places, but not upon peat. The amount of hay yielded by the grass is very great; and it is not infrequently mown three times per year, since it vegetates very early. The younger the leaves and shoots, so much the more readily is the grass eaten by neat-cattle and horses; the older grass should only be fed out after having been chopped fine.

It is to be remarked that Arendt and Knop [†] have determined the amounts of nitrogen and ashes, and have partially analyzed the ashes of a sample of reed canary-grass some $6\frac{1}{2}$ feet high collected in a wood near Leipzig, after the time of flowering. They examined the stalks and leaves separately, and found, in the leaves dried at 100°, 2.64% of nitrogen (equal to 16.50% of albuminoids) and 11.35% of ash. In the stalks dried at 100°, they found 0.67% of nitrogen (equal to 4.19% of albuminoids) and 4.89% of ash. In the ash of the leaves, they found, among other things, about 56% of silica, $5\frac{1}{2}$% of phosphoric acid, $12\frac{3}{4}$% of lime, and $4\frac{1}{2}$% of magnesia. In the ash of the stems, they found nearly 33% of silica, $7\frac{1}{2}$% of phosphoric acid, 7% of lime, and 10% of magnesia. These amounts of silica correspond to $6\frac{1}{2}$% of that substance in the leaves dried at 100°, and $1\frac{1}{2}$% in the stalks.

I have purposely thrown out of consideration an old analysis of reed canary-grass, which has often been cited in this country, that was made by Ritthausen and Scheven.[‡] I deem this analysis untrustworthy, not only because it is altogether inconsistent with my own results, and with those of Gasparin and of Arendt and Knop, but because the remark of Ritthausen and Scheven to the effect that " several of their grasses were collected before flowering (apparently some time before), and kept in water until the blossoms appeared," casts suspicion

[*] In his " Handbuch des Futterbaues," Berlin, 1875, p. 575.

[†] " Die landwirthschaftlichen Versuchs-stationen," 1860, 2. 50.

[‡] Hoffmann's " Jahresbericht der Agrikultur-Chemie," 1859-60, 2. 77.

upon all their results. There is no likelihood that a plant exposed to such an abnormal condition as this would exhibit the same composition as plants that had been left standing in the field, where they could obtain constant supplies of nourishment, until the moment when they were gathered for analysis.

For the sake of ready comparison, it will be well to give here the mean composition of the dry substance of the two kinds of grasses, as determined in this laboratory.

Dry matter of the:	Blue Joint-Grass.	Reed Canary-Grass.
Ash (free from C and CO_2) . .	4.69	7.86
Albuminoids	6.81	11.70
Carbohydrates (including fat)	44.60	43.78
Cellulose (free from ash) . .	43.90	36.66
	100.00	100.00
Fat (ether extract)	2 32	3.36
Nitrogen	1.09	1.88
The per cent of dry matter in the hay was	90.50	90.17

I am indebted to my assistant, Mr. D. S. Lewis, for aid in this investigation.

No. 13. — *Remarks on American Fodder Rations, with Hints
for the Improvement of some of them.*   By F. H. STORER,
Professor of Agricultural Chemistry.

A VERY slight examination of the agricultural literature of this
country will be sufficient to show that our farmers have been slow to
grasp the conception that, other things being equal, mixtures of fodders
of unlike kinds are in general better fitted for the profitable feeding of
cattle than the exclusive use of any one kind of food taken singly and
by itself.

In spite of several highly pertinent and valuable articles * upon the
subject which have been published during the last few years, a vast
amount of ignorance still exists in our midst with regard to the prin-
ciples which determine what kinds of foods may be mixed ; and there
is a lamentable lack of appreciation of the fact that, but for the dis-
covery of these principles, not merely the mixing of rations, but the
whole subject of feeding animals, must necessarily have remained a
matter of the blindest empiricism.

The comparatively small amount of attention that has been given by
our people to these inquiries is the more remarkable, in view of the
fact that tolerably correct views prevail almost everywhere among us
with regard to the special attributes of many kinds of foods.   The
farinaceous character of rice and potatoes for example, and the flesh-
like character of peas and beans are well known to almost every one.
Few Americans need to be told that it is impossible to support the life
of any animal upon simple starch or sugar ; or that in case foods, which
are particularly rich in starch, such as rice or potatoes, were used alone,
very large quantities of them must be eaten because of their one-sided
character ; or, in other words, because of the absence from them of a
proper proportion of the flesh-forming constituents of food.   But
great numbers of our people seem to have no just appreciation of the
fact that the rice and the potatoes are really admirable kinds of foods,

* Compare the tables at the end of Professor Johnson's " How Crops Grow,"
New York, 1868 ; Professor Atwater's articles in the "American Agriculturist,"
for 1875, '76 and '77 ; Mr. A. W. Putnam's Prize Essay in the Transactions
of the Essex (Mass.) Agric. Soc. 1876, p. 121 ; and other papers, by various
writers, in the leading agricultural journals.

that need only to be re-enforced with some appropriate addition in order that they may be used with great advantage as fodder. When, years ago, potatoes were abundant among us, how many farmers could have been found who had arrived at an irreproachable method of utilizing at the farm the unsalable portion of this crop? The problem may have been solved perhaps upon some dairy farms where the refuse potatoes were fed out in conjunction with butter-milk, though even in this case it is probable that, in order to get a sufficient amount of albuminoids, the animals had to consume a larger volume of food than was conducive to their best prosperity.

Empirical devices, such as this with the butter-milk, have been common in human experience. The use of butter-milk formerly by the Irish peasantry in conjunction with their potatoes, has been insisted on by many writers. In Alsatia also, according to Boussingault,* the peasantry always associated large quantities of sour or curdled milk with their potato diet. So, too, the Indians of the Upper Andes, as observed by Boussingault, lived not upon potatoes alone, but upon a mixture of potatoes and a large quantity of cheese. The old New England practice of making the bread of farm laborers, from a mixture of rye and Indian meal was, as it happened, based upon sound physiological principles as well as upon the results of experience. In like manner, the abundant use of baked beans and of cheese here in New England, in the days when but little meat, though much maize, was eaten, serves to attest the advantage of mixing the farinaceous and the flesh-like foods in suitable proportions. According to Payen,† the ordinary food of a Lombard peasant is 3¼lbs. of Indian meal and somewhat more than an ounce of cheese, besides a couple of quarts or more of sour wine, per day. The use of lentils or other kinds of pulse, in conjunction with doura or maize meal, has often been noted by travellers in Egypt and in other eastern countries; ‡ and in rice-eating countries, also, there is the same constant effort to supplement this highly farinaceous food with fish or pulse, or the cheese-like product obtained from pulse.

In case the amount of flesh-like food added to the farinaceous is insufficient in quantity to convert the mixture into a ration of fit pro-

* In his "Rural Economy," New York, 1865, p. 409.
† "Des Substances Alimentaires," Paris, 1856, p. 327.
‡ Compare in this connection the remark of Livingston, cited above, p. 101.

portions, why then, as was just now said, an enormous amount of the food has to be consumed, and much of it worse than wasted, in order to supply enough of the one constituent that happens to be most needed.   According to George Law, the translator of Boussingault's "Rural Economy" (in a note to page 410 of the translation), "the Irish peasantry, who live so much on potatoes, have butter-milk with them at least, often salt herring; and a laboring man, it is said, will consume twelve or fourteen pounds *per diem!*"   So, too, a ration of Irish laborers, given by Payen, reads fourteen pounds of potatoes, and one pound of milk per day, besides water, and small beer when obtainable.   According to Lequerri,* who during a long residence in India paid particular attention to the manners and customs of the inhabitants of Pondicherry, "the food of the Indians is almost entirely vegetable, rice being the basis of it; only the inferior castes eat meat.   But all eat kari, an article composed of fish and legumes, which is mixed with rice that has been boiled in a very little water.   It is only by having seen the Indians at their meals that any idea can be formed of the enormous quantity of rice they can cram into their stomachs.   It would be impossible for Europeans to eat so much of it at a time: they find, moreover, that rice does not nourish them, and they generally retain the habit of eating bread."

Some old experiments of Boussingault on feeding swine upon potatoes and water alone, and on potatoes plus swill and skim milk, show how difficult it is for an animal that is fed upon nothing but a highly farinaceous food to eat a sufficient bulk of this food to keep up the ordinary vital processes, to say nothing of producing flesh or fat. Boussingault found .for example that a hog eight months old and weighing about 120 lbs., that was allowed to have all the steamed potatoes it wished, ate them at the rate of about 15 lbs. of raw potatoes per day, and gained about ¼ lb. of live weight per day on the average, during a term of six months, at the end of which time the animal ceased to gain altogether.   The increase in weight was found to be due in this case to the formation of flesh rather than of fat; and it would appear that, although the animal continued to grow upon the potato diet, it ceased to gain weight when once fully grown. This very hog, with others, had previous to the experiment been gain-

* Cited by Boussingault, in "Annales de Chimie et de Physique," 1838, 67. 418.

ing live weight at the rate of ⅓ lb. per day on a ration of 7 or 8 lbs. of potatoes and a dozen or more quarts of skim-milk.

In this connection, I would cite the following remarks from Mr. Colman's " Fourth Report of the Agriculture of Massachusetts," Boston, 1841, p. 56, relating to the fattening of cattle in the western part of this State previous to 1840..

" The stall feeding of cattle is carried on·to a large extent in the river towns (of Franklin county) and to some extent in the hill towns. In the hill towns, they are usually fatted upon potatoes ; in which case it is not uncommon to tie them in the barn and allow them a bushel [sixty pounds] of well-washed potatoes per day, given at two or more different times, with as much hay as they will consume, and allowing them no water.   One farmer who approves highly of potatoes as feed for fattening stock deems four bushels to be fully equal to one bushel of corn.   He gives as many as the cattle will bear, and this varies from one to two bushels per day. . . . The quantity of the hay which cattle consume under these circumstances, he does not deem important, and thinks the straw of grain will do nearly as well as hay. . . The value of potatoes is differently estimated by different individuals ; some considering five bushels, others rating four bushels, as equivalent to one bushel of corn."

It is manifest that a small addition of oil-cake to these excessively farinaceous rations would have been meritorious, and it should be said that Mr. Colman found one or two farmers, but no more, in the locality here in question, who were of the opinion that oil-cake is of great value for fattening cattle.

It is to be observed that the foregoing cases, though extreme, are not exceptional.   Similar examples might be adduced in respect to almost any other article of food.   For the researches of chemists have shown not only that all kinds of foods and fodders may be regarded as belonging to one or the other of two great general classes, — viz., the albuminous or flesh-like foods on the one hand, and those that are comparatively rich in carbohydrates on the other, — but that from the chemical point of view no single one of them is perfect in itself or. adapted to all kinds of cases.   Provided labor were cheap, and the several different kinds of foods were equally accessible, there would be found very few cases indeed where the best economic results could be got by the use of one single kind of fodder.   No matter what the

material might be, it would almost of a certainty contain either too little or too much albuminoid matter to be used advantageously by itself. From the chemical point of view, even young pasture grass — which our farmers are apt to regard as the most perfect kind of cattle food, and which at first sight would really seem to be all-sufficient in itself — must be deemed an unnecessarily luxurious ration ; * for the proportion of albuminoids to carbohydrates contained in good pasture grass is as 1 to 2 on the average, while the experience of German farmers has shown that milch cows can be kept perfectly well upon food in which the proportion of these constituents is no larger than 1 to 4 or 1 to 5, and that even for growing animals, such as calves, the proportion of albuminoids to carbohydrates need be no larger than 1 to 3 or 1 to 4.

The merit of pasturing, considered as one economical method of feeding animals, depends not merely, nor even chiefly, upon the chemical composition of the young grass. It depends upon the comparatively small amount of care, labor, and trouble, that need to be given to the pastured animals ; upon the vigor and health which the animals acquire in the field ; and upon the excellent quality of the meat, milk, butter, and cheese, which are produced by them. It can, indeed, hardly be disputed that, in respect to the quality of the products obtained from them, animals generally do better at pasture than when kept up and fed with mown grass, or soiled, as the term is. But it may well be questioned whether these advantages might not still be preserved, and a larger profit gained in some cases, by stocking the pasture so heavily that its grass alone could not fully support the animals, and serving out to them in the field some suitable food or mixture of foods to complement the grass, as well as to make good the lack of it. Of course, in the case here supposed, grass is taken at its best. It is argued that the pasture is super-excellent, that it is always green, and that the animals get from it nothing but young tender grass. Practically, animals do select such grass from most pastures that are not fully stocked or suffering from drought.

As regards hay, it is readily conceivable that grass might be cut and dried at that particular moment of its development when the hay would be of such composition that it could be used by itself as a wellnigh perfect food for many purposes. But practically, early-cut rowen

* Compare Werner's " Handbuch des Futterbaues," Leipzig, 1875, p. 808.

and young clover excepted, hay, as commonly made, is hardly rich enough in easily digestible albuminoids to serve the best possible purpose as a production ration when used by itself. It needs to be re-enforced by some slight addition of a richer kind of food. Hay of average quality is well fitted, it is true, for maintaining animals from which no very large amount of milk or flesh or other product is expected. That is to say, by feeding them with hay alone, the animals may be made to produce moderate amounts of milk or of work, or even to become partially fattened; but, as is well known, something more than ordinary hay is needed for obtaining a really abundant yield of the products in question.

A somewhat similar remark will apply to Indian corn as to young pasture grass, though in a contrary sense. The average proportion of albuminoids to carbohydrates in maize is as 1 to 7 or 1 to 8 which would go to show that this kind of grain is neither rich enough in albuminoids to be used by itself to the best chemical advantage, nor well fitted to be used, as it so often is, by our farmers, to "re-enforce" other kinds of food that are in themselves poor in albuminoids.

There is no need to urge, in this country, that maize has many commendable qualities. Its richness in oil and starch; its easy digestibility when crushed or ground, or swollen by soaking or scalding; its cheapness; its palatableness to all kinds of stock; and the excellent quality of the beef or pork that have been fed with it, — are too well known to be commented upon. But the chemical composition of the grain, as well as practical experience in feeding animals, shows that maize taken by itself is better adapted for fattening adult animals, or for finishing the fattening, than for rearing young animals or for producing milk. There is good reason to believe that, except for fattening swine of a certain age and weight, maize should by good rights be mixed with some other more highly nitrogenized food, in order that its constituents may be thoroughly utilized; and there is every reason to believe, also, that maize is by no means so well adapted for re-enforcing rough forage as a number of cheap foods that are more highly nitrogenized.

In considering whether our farmers have been accustomed to use their Indian corn to the best possible pecuniary advantage, it should be understood clearly that the question of thoroughly utilizing each of the chemical constituents of a food need not necessarily coincide with that of the most economical use of the food. The fattening of hogs

and horned cattle upon maize alone, in the comparatively inaccessible portions of our western States, though undoubtedly somewhat·wasteful of the maize, may perhaps be the most economical method of utilizing the crop that could be devised for these particular localities, under the conditions of labor and capital, and with the means of transportation, that are to be found there. The object in feeding out the grain in this case is merely to concentrate the crop in the cheapest possible way to such an extent, or rather to bring it into such form, that it may· be transported to a market with profit. According to Russell,* "the usual allowance for 100 pigs (fed in this way in Ohio) is eight bushels of shelled corn a day." "The hogs were of good sorts, lazy, good-tempered-looking brutes, and getting into prime condition; their average weight would be about one hundred and sixty pounds."

From the chemical point of view, another method of disposing of the maize crop, which has often been adopted at the West, seems preferable to the foregoing. The distilling of whiskey from the corn, or, in other words, the conversion of the farinaceous portion of the maize into alcohol, removes those constituents which made it a one-sided fodder ; while the nitrogenous "wash" or swill that is left as a residuary product·of the process may be fed to swine or neat cattle with advantage. It is evident, moreover, that the swill might be mixed with maize and with fodder-corn in such proportions as to form very judicious rations.

It is true, in general, that, in case any farmer should propose to use in conjunction with maize some kind of fodder that is more highly nitrogenized, he ought to determine by calculation whether it would not be more economical in his particular locality to let some of the constituents of the maize go to waste, as they must in most instances when the grain is fed out by itself, than to be at the cost of pro-curing the nitrogenous food.

Suppose, for example, that upon a given farm 20 bushels of peas could be grown to the acre, or 50 bushels of maize. The comparative cost of getting the 1,200 lbs. (20×60) of the one, or the 2,800 lbs. (50×56) of the other crop, year after year, would have to be con-sidered ; and the value of the straw and stalks from each crop, as well as the chemical facts that such a pea crop would yield, on the

* "North America; its Climate and Agriculture," by Robert Russell, Edin-burgh, 1857, p. 79.

average, some 270 lbs. of albuminoids and 675 lbs. of carbohydrates
(including about 24 lbs. of fat) to the acre; and such a corn crop
about 278 lbs. of albuminoids, and 2,000 lbs. of carbohydrates (includ-
ing 156 lbs. of fat).

It is true, no doubt, that peas, or a mixture of peas and maize, are
better fitted for feeding growing swine than maize by itself. But, on
the other hand, there is actually more nutriment of one kind and
another in the 2,800 lbs. of maize than in the 1,200 lbs. of peas.
The 2,800 lbs. of maize, fed out without any addition, would, of
course, be competent to rear and fatten, though in a chemically
wasteful way, a certain number of pounds of pork, at a cost in terms
of money which might be ascertained with no great difficulty in any
given case; and it might well be true in many localities — so easy
and certain is the cultivation of maize — that the cost per pound of
the pork would not be lessened if the maize were mixed, even in the
best possible proportion, with the peas.

It is manifest that a question such as this, involving, as it does, so
many different considerations relating to methods of tillage, the rota-
tion of crops, and the manner of conducting a farm, will have to be
determined by each individual farmer for himself. All that the chem-
ist can do is to accumulate evidence relating to his own department
of the subject, and call the farmer's attention to some of the princi-
ples upon which the decision of such a question should be based.

In like manner, and perhaps more emphatically, it is, generally
speaking, true that the use of simple grass, upon a cattle ranch or in
regions of rocky hill pastures, is the best possible economic use of
that kind of fodder; though in many parts of the country the inquiry
may even now be pertinent, whether an addition of corn, or of mature
fodder-corn, or of apples or of potatoes in their season, to young
pasture grass, might not be economical and wise.

On contrasting our American methods of farming with those which
prevail in Europe, it will be noticed immediately that only compar-
atively small amounts of highly nitrogenous foddering materials are
used in this country. We have pasture grass, to be sure, and red
clover in some localities. The cow-pea·is grown as a forage crop in
some districts at the South; and mixed peas and oats have been
cultivated in some scattered localities at the North. Skim-milk and
butter-milk are given to swine. But it is nevertheless true that our

fodder rations have almost everywhere been remarkably poor in nitrogenous constituents, up to a comparatively recent period, when some efforts have been made to supply the deficiency.

The reason of this general lack of nitrogen is not far to seek. It depends doubtless upon the fact that Indian corn, which lies at the very foundation of American agriculture, is a plant so nearly fitted to serve the purpose of a complete mixture of foods, and is so easily grown withal, that our farmers have had comparatively little incentive to cultivate any other crops for foddering purposes beside maize and grass. But it would not be difficult to show that maize has been somewhat overrated by our people, or rather that it has not received quite fair treatment at their hands.

For swine of a certain age and weight, that is to say, for swine that have attained a considerable development of frame, or growth, as the term is, it would appear that maize fed out by itself may play the part of a well-nigh perfect food. There are experiments upon record, at all events, which show that swine of improved breeds, that are rather more than six months old, and are already fairly advanced in the process of fattening, prosper exceedingly upon rations which contain albuminoids, carbohydrates, and fat, in proportions similar to those in which these constituents occur naturally in maize. But it is probable that the period during which maize would be the best possible food, even for swine, is not very long, since the requirements of these animals differ continually as they become larger and fatter. It is not impossible, indeed, that for very fat hogs a food even more highly carbohydrated than maize would be preferable to it. For poultry, also, at a certain stage of the fattening, maize alone may perhaps be a practically perfect food; but so strong a remark as this could hardly be applied in respect to any other animals beside poultry and swine, in spite of the excellence of maize when used for purposes of fattening, as an addition to the food of all kinds of cattle. Moreover it is a well-established fact that for young growing swine a more highly nitrogenized food than maize is greatly to be preferred. Many an American farmer has expressed this truth in other language by complaining that the first 100 pounds of corn-fed pork cost more than the second. It is worth noting, in passing, that, although this practical remark must necessarily be true of maize, it need not be true with respect to other kinds of foods. Nitrogenous foods may be had for the growing almost

everywhere; and, as was said before, it is a mere question of experience whether it would be worth the while to raise them in a given locality, for the purpose of supplementing a diet that is too highly farinaceous.

The old practice of allowing swine to graze upon grass or clover, which formerly prevailed in Europe, and which has frequently been resorted to in our Middle States, may perhaps have obviated the very difficulty now in question; and so, perhaps, may the practice of pasturing swine upon growing peas in some of the Southern States. The judicious use of flesh-meal, as an addition to maize, for feeding growing swine, would seem to be well worthy the attention of farmers in many parts of the Western States.* According to Drake,† "The Indians [of South-eastern Maine], whose chief dependence in summer was upon shell fish, complained that the English swine watched the receding tide, as their women were accustomed to do, feeding on the clams they turned up with their snouts."

It is noteworthy, however, that, when by chance our farmers have happened to have easy access to foddering materials which are more highly nitrogenous than maize, they have been accustomed to use them freely and to value them highly. Witness, for example, skim-milk and butter-milk, the brewers' grains,‡ that are used to such an enormous

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* A receipt published in this vicinity some years since (see "New England Farmer," 1863, **15**. 190) reads as follows: "For a mess sufficient to feed six store hogs and eight small shotes once, take 6 lbs. of beef-scraps, and boil them in 2 pails of water, scald in 2 quarts of cob-meal, add 6 pails of water, and feed out the mixture while it is still warm. Two feeds per day of this mixture are said to be sufficient to keep breeding sows or store pigs in good condition." The writer, whose chief business was to raise pigs and shotes for sale, adds: "I slaughtered two fat hogs last fall, that had been fed in this way until the time to fatten them arrived; after which they had their usual feed thickened to a dough with corn- and cob-meal only; and at the age of sixteen months the two weighed over 1,000 lbs."

† In his "Nooks and Corners of the New England Coast," New York, 1875, p. 113.

‡ As ordinarily used, brewers' grains contain about three-quarters their weight of mere water, which makes their transportation costly at the best, and limits the use of them to comparatively narrow districts. But it is a question whether it might not be well, in some of our cities, for the brewers to dry their grains, and so convert them into a really concentrated nitrogenous food that could be carried about or stored like any other kind of merchandise. Dried brewers' grains are an article of commerce in England, and are esteemed by practical men. A sample analyzed by Anderson ("Transactions of Highland Society," July, 1856, p. 358, through Henneberg's "Jahresbericht für 1855–56," p. 51) contained 6.49 % of water, 16.14 % of albuminoids, 4.74 % of ash, and 72.63 % of other matters.

extent by farmers in the vicinity of our cities, and the swill of cities and that from distilleries.   Bran also, which is decidedly more nitrogenous than maize, and of late years cotton-seed meal and Hungarian grass, are coming into general use.

As has been suggested, already, the difficulty with regard to Indian corn, and it is a difficulty which has led to many errors in the foddering practices of the American people, is that, in spite of its richness in oil and its easy digestibility, it is not sufficiently nitrogenous to be used to the best advantage in conjunction with many of the poorer kinds of fodder that need to be consumed at the farm.   I have been strongly impressed by the truth of this remark when occupied with the analysis of the various foddering materials, such as bog-meadow hay, apples, shorts, broom-corn seed, and pumpkins, that have been reported upon in the Bussey Bulletin during the last five or six years. I have noticed so many instances where the use of these materials, as described by our farmers, seems to have been erroneous, or, at the least, injudicious, that I find it difficult to escape the conviction that the whole subject of foddering has been very generally misunderstood in this country.   It seems plain, at all events, that there is urgent need of the careful study of the subject by our farmers in numberless localities.

The object of the present paper is to call attention to some special instances where the use of common foddering materials appears to have been wise or faulty, to enforce one general principle upon which judicious foddering must depend, and to urge that, in many of the American fodder rations that have been employed hitherto, the proportion of albuminoids is, chemically speaking, insufficient.   For myself, I incline to the belief that the proportion of albuminoids in many of the fodder rations of this country is insufficient from the economical, as well as from the chemical point of view ; or, in other words, that it is incompetent to produce, in practice, the greatest money profit in the localities where the rations now in question are actually used.

The experience of our farmers, in the use of apples for feeding swine, affords many examples of both good and bad practice, as I have observed somewhat in detail since my previous article on this subject was written.   It is plain, moreover, from what has been published upon the subject in our agricultural papers, that no clear and definite

conception of the right way of feeding apples has ever obtained general credence among us. Analysis shows that apples are extraordinarily poor in respect to nitrogenous constituents, and indicates clearly that they should be fed out in conjunction with some highly nitrogenized food, such as peas or flesh, for example, as has been set forth on page 367 of volume 1 of this Bulletin. But, in point of fact, the system there described of feeding swine with apples and mixed peas and oats, was successfully practised forty years ago, here in New England, by several different farmers. Moreover, many farmers have found their advantage in using apples with sour milk and swill, which are both highly nitrogenized substances.* Bran, also, which contains a tolerably large proportion of nitrogen, has been used with advantage in conjunction with apples. Indeed, there is good reason for believing that the use of apples for feeding hogs would have become a very common practice if these original correct methods of using the fruit could but have been once generally tried or believed in. But when corn-meal and cob-meal came to be substituted for the peas, the swill, and the bran, it is not surprising that the apple mixture quickly fell into disrepute. There can be little question that windfall apples could be fed to hogs with profit in conjunction with the highly nitrogenous meat scraps, cracklings, or greaves, which are left as a résidual product in the rendering of tallow by the chandlers. Several instances of the successful use of this flesh scrap for feeding hogs, both by itself and in conjunction with cob-meal, have been reported.†

The thought suggests itself, in this connection, that the old Scotch and English system of feeding hogs with potatoes, plus pea-meal, or the meal of mixed peas and oats, was, chemically speaking, preferable to the use of potatoes with corn-meal or cob-meal, as was formerly the custom hereabouts.

The use of apples for feeding neat-cattle, in conjunction with bog-meadow hay or other rough forage, and oil-cake (cotton-seed meal), could hardly fail to be advantageous ; and the pomace from cider-mills, also, as was said in a previous article, has unquestionably considerable value as cattle food. It is to be noted, withal, that, in

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* Compare (for pea meal) "New England Farmer," 1834, **13.** pp. 100, 316; 1835, **14.** 29; 1838, **16.** 205; (for swill, sour milk, &c.,) 1826, **5.** 82; 1838, **12.** pp. 172, 203; 1868, **15.** 70.

† Compare "New England Farmer," 1835, **14.** 83, and 1868, **15.** 191.

respect to their chemical composition, apples are specially well fitted to supplement the too highly nitrogenized young pasture grass, described on page 141, though in late autumn, when the fruit is to be had most abundantly, there is probably the least need of adding to the pasture grass a food rich in carbohydrates.

As has been already said, even English or upland hay, as ordinarily harvested in this country, is hardly rich enough in easily digestible albuminoids to yield the best results as regards animals from which milk, or flesh, or work is required; and this remark is most emphatically true, in respect to bog-meadow hay, and the hay of most salt marshes, as was insisted before in vol. **1.** pages 353–360. There cannot be the least question that enormous quantities of these rough hays could readily be put to much more profitable use than they are now, by using them in conjunction with cotton-seed meal, oil-cake, or some other appropriate addition. The wide-spread European practice of fattening cattle upon straw and roots, re-enforced with a small proportion of oil-cake, is of interest, of course, in this connection in that it points out one good way of dealing with rough forage, although this way may possibly not be the very best for the farmers of this vicinity.

Clover when properly cut and cured, is to be classed among foods that are rich in albuminoids, and there can be little doubt that this plant has not infrequently served in American practice to correct the too highly carbohydrated rations of which complaint is here made. As is well known, clover is grown to a considerable extent in some parts of this country; and it appears to have been grown formerly here in New England to a much larger extent than it is now. Moreover, the analogous plant lucerne or alfalfa is a standard crop in California, as it is in many parts of Europe. In young red clover, not yet in blossom, the ratio of albuminoids to carbohydrates is as 1 to rather less than $2\frac{1}{2}$; for clover plants in full blossom, and for good clover hay, the ratio is 1 to 3, or 1 to $3\frac{1}{4}$. In young lucerne plants, a foot high, the ratio is 1 to rather less than 2, and in lucerne hay it is as 1 to $2\frac{1}{4}$. Young clover, eaten before the time of blossoming, is manifestly too rich in albuminoids to be, chemically speaking, an economical food; and in many parts of Europe, where clover is used for soiling cattle, it is customary to mix chopped straw with the young plants in order to avoid the waste of albuminoids that would occur if the young clover were fed out by itself. Clover-hay, carefully cured, from plants that have

been mown in early blossom is doubtless well suited, when fed by itself, for producing milk or the like; but there is a difficulty with full-grown clover, in that the old stalks are not only hard and bulky, but, comparatively speaking, indigestible, and on that account not so well adapted for producing milk or flesh as the mere analysis of the plant would indicate.* For the same reason, that is to say, its comparative indigestibility, clover hay, as ordinarily harvested, is not particularly well fitted to serve as a nitrogenous re-enforcement to ordinary hay or straw. In hot dry climates, moreover, like our own, there is great risk of losing much of the best part of the clover plant during the process of hay-making, for the crisp dry leaves are particularly liable to be broken into fragments too small to be collected by the rake. But without their leaves the stalks of mature clover are by no means either a well-proportioned or a concentrated kind of food; on the contrary, they are to be regarded as of the nature of straw.

The white clover of our pastures is to be classed, of course, as pasture grass; and all that has been said of young grass will apply to young white clover, with equal or even with greater force. From the chemical point of view, the young clover needs to be supplemented with a less highly nitrogenous food.

The old discussions here in New England, as to the fodder value of broom-corn seed, which have already been referred to on page 96, well illustrate the difficulty of dealing with a highly one-sided kind of food, in the absence of any just knowledge of the principles which should determine the mixing of foods. Pumpkins, on the other hand, which contain a fair proportion of nitrogenized constituents (see page, 83,) have commonly been used, as it happened, in a very proper way, and have consequently been held in high estimation. The use of pumpkins as an addition to hay or fodder-corn for feeding cattle commends itself, and the not uncommon practice of feeding hogs of a certain age with boiled or steamed pumpkins, plus corn-meal, is, chemically speaking, very much more commendable than the use of corn-meal with apples, as mentioned above, or even with the use of corn-meal and potatoes.

The question has sometimes been asked, seriously and in good faith,

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* Compare the remark of Boussingault, in his "Rural Economy," New York, 1865, p. 392, as well as the more recent experiments of the German agricultural stations.

in our agricultural papers, whether fodder-corn has merit enough to warrant the growing of it; and in general it may be said that the title of this kind of forage to consideration and esteem, has been often and vigorously debated by American farmers. The truth of the matter is, that fodder-corn is an extremely valuable food, that needs only to be used understandingly in order that it shall commend itself. When cut sufficiently young, fodder-corn contains a tolerably large proportion of albuminoids; and there is doubtless some one particular stage in the development of the maize plant at which it is fit to be fed to milch cows by itself, without any addition: but when allowed to pass this stage or to approach maturity, as when it is grown to be cured for winter forage, fodder-corn is found to contain only a comparatively small proportion of albuminoids, and consequently needs to be supplemented by some more highly nitrogenized food, in order that it may be used to the best chemical advantage. The composition of mature fodder-corn has been carefully studied by Professor Johnson, of New Haven, whose conclusions in respect to its great value will be found very clearly set forth in a recent number of the "American Journal of Science," March 1877, p. 202.

In fodder-corn of two varieties "harvested at a time when the plants had an average height of ten to twelve feet, and contained a good many imperfectly developed ears, some of them with nearly ripe kernels," Johnson found the proportion of albuminoids to carbohydrates as 1 to 8 @ 11, very nearly. Wolff, in his tables, gives the ratio 1 to 9 @ 10 for fodder-corn; and for maize straw, i. e., stalks and leaves of ripe plants from which grain has been gathered, he gives the ratio 1 to 13. In samples of green fodder-corn, collected in Germany just before flowering, ratios of 1 to $3\frac{1}{3}$ and 1 to $4\frac{1}{3}$, have been noticed; and, in a German sample cut in full blossom, the ratio was 1 to $7\frac{1}{3}$.*

An interesting practical point to be decided in connection with the use of fodder-corn is, whether the vines of peas or beans or vetches might not be grown with advantage, even at the North, for the express purpose of supplying those chemical constituents which the fodder-corn lacks. The comparative difficulty of curing the young vines of leguminous plants, without waste or deterioration, is, of course, an objec-

* Werner's "Handbuch des Futterbaues," Berlin, 1875, p. 602, and Dietrich and Kœnig's "Zusammensetzung der Futterstoffe," Berlin, 1874, p. 4.

tion to such crops, and the machines employed for ordinary hay-making are not specially adapted for use in curing the vines; but it may, nevertheless, well be possible that, when used to supplement fodder-corn, the profit from pea hay would much more than compensate for the trouble of getting it. Perhaps the European system of preserving green forage by fermentation, that is to say the making of " sour hay," may sometimes be found useful in this particular case. For example, if sour hay were to be made from the forage, it might perhaps be found advantageous to grow fodder-corn and running beans (some free-growing tropical variety) together as a mixed crop which would be preserved in one common pit.

In previous papers, I have repeatedly alluded to the kinds of foods at the disposal of our farmers which are highly nitrogenized and fit to be used in the compounding of well-proportioned rations. Cotton-seed meal and other oil-cakes, brewers' grains, malt sprouts, peas, beans, * and all kinds of leguminous seeds, fish, and flesh, are all highly nitrogenous. So, too, are Hungarian grass, when mown young, clover, mown young and cured without too much handling, and a great variety of other leguminous plants, such as peas and vetches. Even young fodder-corn is a nitrogenous food as has just been stated. In general, it may be said that nitrogenous food could be collected in abundance by mowing very young grass or grain, or almost any other young plant. The reason why this mode of procuring forage is not practised more frequently is, simply, that the total yield of hay from the young plants would be very small as compared with the amount procurable from more mature plants. In a word, the large quantity of hay obtainable from the older plants is, generally speaking, worth more than the small quantity obtainable from the young plants, in spite of the superior quality of the latter. The labor of harvesting the young plants, moreover, might in some cases be very nearly as great as that of getting the mature crop.

In former years, the nitrogenous food offered by young green plants was not infrequently put to immediate use by pasturing sheep upon the grain fields in spring and permitting the animals to eat down the first growth of leaves, or by mowing the grain fields at this season. Indeed, it was at one time proposed in Germany † to systematize the matter

* In some parts of Great Britain, cow-feeders are said to be specially partial to bean meal.

† By Professor Hadelich, of Erfurt, Beckmann's " Beyträge zur Œkonomie," &c., 1782, 6. 447.

by sowing rye in June, mowing it in late summer, or in September before the shooting of the stalks, and making it into hay as if it were so much grass.   After mowing, the plants were left to themselves to take a fresh start, as if the seed had just been sown ; and next year the crop was allowed to grow in the usual way, and the grain was harvested in due course.   A somewhat similar idea has been carried out by some New England farmers, who, in renovating old pastures, have sown rye together with grass seed, and have subsequently allowed cattle to feed so constantly upon the young plants that the grain stalks could never find an opportunity to shoot up.   When treated in this way, rye is said to show great endurance, and to yield excellent pasturage through several years.

It has been often urged as a practical objection to the mowing or pasturing of fields .of winter grain that the grain crop proper suffers more than the amount of forage obtained is worth, and it is manifestly questionable on the face of the matter whether it is proper to tamper in this way with the growth of a crop.   It should be determined, by experiments, in how far the natural needs and habits of the grain plant can be interfered with by such systems of pruning, without serious injury to the proper crop.   The subject is an interesting one for its own sake, and would seem to be worthy of more careful investigation than has been given to it hitherto.

Bran or shorts, as is well known, is more highly nitrogenous than the grain from which it has been derived ; and all the products known as middlings, fine feed, and mill feed, contain a larger proportion of nitrogen than the meal or flour from which they have been separated by sifting, though, as I was at pains to show in a previous paper, the wheaten bran or shorts, &c., of commerce are all rather less highly nitrogenous than has been commonly taught hitherto in works relating to the chemistry of agriculture.   In the following table, A represents the average composition of American shorts as determined by analyses made in the Bussey laboratory ; * B represents the average composition of European bran as deduced from a critical examination of all the analyses accessible to me in 1872 ; * and C gives the average composition of European brans as obtained from Dietrich & Kœnig's collection † of nineteen recent analyses, none of which were

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* See Bulletin of the Bussey Institution, 1. 86.

† In their "Zusammensetzung und Verdaulichkeit der Futterstoffe," Berlin, 1874, pp. 85, 86.

included in my own collection (B) of earlier analyses. For the sake of comparison, the average composition of American middlings and ship-stuffs is given in line D.

	Water.	Ash.	Albuminoids.	Carbohydrates, including fat.	Cellulose.	Fat.	Nitrogen ratio.
A	11.65	4.28	11.75	64 42	8.29	4.24	1 : 5.5
B	13.24	4.10	13.44	60.22	9.00	3.62	1 : 4.5
C	12 75	5.24	13.76	60.11	8.60	3.52	1 : 4.4
D	12.25	2.20	10.86	69.67	5.02	2.94	1 : 6.4

It will be seen that Dietrich & Kœnig's figures, though deduced from analyses of whose existence I had no intimation until long after the publication of the averages given in the table, are surprisingly like the figures given in line B; and that they have confirmed most fully my conviction that wheaten bran had been somewhat overrated in respect to the average amount of its nitrogenous constituents. The ratio of albuminoids to carbohydrates in A is 1 to $5\frac{1}{2}$; in B, 1 to $4\frac{1}{2}$; in C, 1 to $4\frac{4}{10}$ very nearly; and in D, 1 to $6\frac{4}{10}$. Taking the mean of A, B, and C, it is as 1 to $4\frac{7}{10}$, which is distinctly lower than the ratio (1 to 4) given in Wolff's tables, and commonly adopted hitherto. The ratio of albuminoids to carbohydrates in the ordinary grains is 1 to 5 or $5\frac{1}{2}$ in wheat and oats, 1 to 5 @ $6\frac{1}{4}$ in rye, and 1 to 6 or 7 in barley.

In respect to milch cows, the application of the ideas above presented, or, indeed, the administering of any new or unusual food will need to be set about cautiously, as every practical man knows. There is danger of making cows feverish if they are fed too high; there are many kinds of food otherwise excellent that impart an unpleasant taste to the milk or butter, or injure the texture and appearance of the latter; and it is, in general, an easy matter to diminish the yield of milk by giving the animal foods which produce diuretic or purgative effects, or which in any way interfere with the normal processes of digestion.

But all this has very little bearing upon the truth of the doctrine here presented. The intrinsic value of turnips and cabbages * and

* For an interesting debate upon the influence of such food upon the flavor

oil-cake as foddering materials should not be lost sight of, even if these substances, when incautiously used, are peculiarly liable to do positive harm, as regards the quality of the milk or the butter obtained from the animals that have been fed with them. The facts that turnip-tops are highly nitrogenized and are excellent food for cattle are fixed and permanent, no matter if the tops do, even more than turnips themselves, sometimes impart an abominable flavor to the milk of cows that have eaten them. The moral to be drawn is not that such foods should be banished from the farm, but that the limitations to which each particular food is subject should be accurately made out and allowed for.

Not only should the best possible way of using each kind of food be determined, but all the circumstances and conditions under which a given food may be used with advantage. Many a material that would be dangerous if administered carelessly, or in too large quantity, will do excellent service when used in small proportion as an addition to other food. Above all, pains should be taken to find out upon each and every farm the best possible fodder mixtures for that particular farm.

The cases mentioned above, where flesh in the form of greaves or cracklings or chandlers' scraps was used with advantage for feeding swine, are but as one instance among many that might be cited in favor of the use of animal food. Crampe, in a lecture upon this subject, has urged that, in the old days when swine were fattened upon mast in Europe, much importance was attached to the so-called "worm-mast," as well as to that afforded by acorns and beech-nuts. It had been often observed, in fact, that it was not the nuts alone that fattened the swine; but that the snails, worms, insects, &c., that were consumed by the animals, had an appreciable influence in promoting their growth. It was an accepted creed in Germany that, after a snowless winter with hard frosts, the autumn would be bad for masting swine, no matter how abundant or how excellent might be the crop of acorns and beech-nuts; the inference being that so many snails and insects and larvæ of insects were destroyed during the severe winter by the freezing of the soil, that the supply of animal food for the swine was insufficient to enable them to fully profit by the nuts. This point would appear to be particularly well taken, since nut-mast

of milk and butter, and for statements of means of avoiding the unpleasant taste, see "Eighth Report of the Secretary of Connecticut Board of Agriculture," 1874–75, pp. 38–43.

is a highly farinaceous food.   The proportion of albuminoids to carbo-hydrates is no more than 1 to 18 in acorns, and 1 to 15 in chestnuts. The significance of insects in the food of poultry, and particularly in that of turkeys, has often been commented upon ; and so has the habit of sheep and neat-cattle of eating fish in several poor countries that border upon the sea.*   Several examples of the systematic use of flesh-meal for feeding animals have recently been reported from Europe ; but there is little need of looking abroad for evidence upon this subject, in view of the experience of a number of farmers in Maine, who, for some years past, have fed sheep, swine, and horned cattle upon dried fish-scrap with great advantage.   In the " Report of the Secretary of the Maine Board of Agriculture," for 1869, **14.** 60, Mr. Wilder states his experience as follows : —

" From careful observations, close calculation, and long experience in sheep raising, I have come to the conclusion that fish offal used as food for sheep, is not only cheaper, but much superior to any other kind of provender I have ever used.   I keep about one hundred sheep, have fed fish offal to them for the last ten years, and I have wintered my sheep for the last three winters on threshed straw, with one half pound per day to each sheep of dried fish pomace or one pound of green (as it shrinks one-half in drying), and they come out in the spring in much better condition than when fed on good English hay with Indian corn. . . . The fish offal which I use is made from herrings, caught in weirs, seined and dipped into boats, then taken to the press-house, where they are salted the same as for smoking; after which they are cooked, and the oil pressed out, leaving a pomace for which sheep are more eager than for grain."   Mr. Wilder states, furthermore, that in his experience both the fleeces and the carcasses of the sheep fed with the fish scrap are heavier than those from sheep that have been fed with hay and maize.

In the following year,† Mr. Wasson, of Ellsworth, speaking of his experience with fish scrap as cattle food, said : —

" I am experimenting now for the second year in the use of ' chum ' as we call it, or refuse porgie (*Alosa menhaden*), as food for sheep and poultry, substituting it for Indian corn and turnips.   I have been feeding for several years turnips and corn to my sheep, and my experience thus far is that pound for pound, as a provender for sheep, the ' chum ' is worth as much as corn.   An acquaintance of mine has been experimenting for two years or more, in feeding it to his milch cows.   He has abandoned that now

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* For an example, at Provincetown, on Cape Cod, in our own State, see "New England Farmer," 1827, **6.** 145.

† " Report Sec. Maine Board of Agriculture," 1870, **15.** pp. 80–84.

on account of the unpleasant flavor which it imparts to the milk; but his experience has been that for young growing stock or cows that have dried up, nothing else will give such rapidity of growth, or place them in so good condition in the spring. A gentleman who has been feeding 'chum' to his sheep for two years past, and is giving it again this winter, told me that it would increase the weight of the fleece one pound per head over and above what he would get by feeding any thing else to his sheep, Indian corn only excepted. . . Those who have used the 'chum' (as a fertilizer) associate with the name that peculiar (and highly offensive) odor which attaches itself to it unless it is properly prepared. We are now learning the proper way to prepare this refuse. It is taken from the press, and dried until it is as inodorous as dried cod-fish, and may be handled without imparting any offensive smell at all; and it is surprising to see with what avidity sheep and cows will eat it. They will pick up every bone, no matter how large or how small. The question has been put to me, if we did not render ourselves liable by allowing our sheep to eat the bones, as it is impossible for them to eat the 'chum' without the bones. I have never noticed any injurious effect from that. To show how eager they are for it, I will mention that I feed it to my sheep in the morning, and they cannot be quieted until they receive their 'chum.' I feed at the rate of two quarts a day for every twelve sheep. . . . There is no salt used in the preparation of the 'chum' I use; so that it is as fresh as when the fish came from the water. Sheep or cattle readily learn to eat it. It is natural for them to want such kinds of food."

To these remarks, Mr. Secretary Goodale added the following: —

" With regard to herring, the practice is almost universally to pickle the herring, and more or less salt remains in the 'chum.' Porgie 'chum,' on the contrary, is usually quite fresh. I have had this matter of feeding refuse fish to sheep under observation for ten years or more. I have not found a single man who has given it a fair trial with good material, who has not found it successful. And if you will look at its composition, you will not wonder. . . . The fish will furnish, in an inoffensive form, a highly nitrogenous food, which will supply those elements of growth in which our poorer forage products are deficient. It will come in mainly as a supplement to another food. We have a good deal of bog or swale hay, and of other inferior fodder, and this is lacking mainly in nitrogenous elements, those constituents which go to make flesh; and, by giving a moderate amount of dried fish, you supply just what is lacking in the poor fodder, and it will enable you to get along with a much smaller amount of good hay, and thus make your hay go a good deal further. . . What ought to be done all along the coast is this: just as soon as the fish refuse comes from the press, it ought to be dried by artificial means. . . . It ought to be dried by artificial heat, then it should be ground, and all possible danger to cattle from the bones would be avoided. It can then be used for any cattle except cows giving milk. It would give the milk a

more or less disagreeable flavor. But it will furnish that which will help to make flesh, fat, and bone, and that is the greater desideratum generally.''

The practicability of using fish scrap would seem to be completely proved by the foregoing very explicit and satisfactory statements, not to dwell upon the corroborative European experience with both fish and flesh, of which mention was just now made. The only point to be insisted upon is the necessity, in order to avoid danger to the animals, of having the refuse matters salted or smoked or pressed or dried in such wise that they shall be preserved from putrefaction. But there would be no great difficulty in doing this ; and it will be done, doubtless, the moment our farmers begin to make any general inquiry for meat-feed.

Much attention has been given of late, by the agricultural chemists of Europe, to the question of the comparative digestibility of the various constituents of different kinds of fodder ; and many experiments, in feeding animals and analyzing their food and their excretions, have been made to that end.   This subject, also, is one of very great importance, that needs to be studied by our farmers in due course.* But, in the present state of popular knowledge in this country, it seems necessary, first of all, to lay special stress upon the great general conception of the complementary character of different kinds of foods. If that conception were once clearly grasped by practical men, and the habit acquired of applying the idea to the details of actual farm practice, it would be a comparatively easy matter for the farmer to pass forward to the consideration of the additional or supplementary, and perhaps still more important, question, as to which of the various fodders are the more or the less digestible among their respective kinds.

I have purposely chosen a number of old examples for illustrating the foregoing remarks, in the belief that it is easier to gain knowledge by contemplating the practices of our predecessors than by disputing special errors that are still in vogue.

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* It has been expounded already, in a very able manner, by Professor Atwater in a number of papers in the "American Agriculturist" for 1875 and 1876.

No. 14. — *Results obtained on growing Buckwheat in Equal Weights of Pit-Sand and of Coal-Ashes.*   By F. H. STORER, Professor of Agricultural Chemistry.

SOME experiments made at this laboratory in 1872–73 on the agricultural value of the ashes of anthracite, while showing that the ashes were slightly inferior to an equal bulk of pit-sand, such as underlies the plain field of the Bussey Institution, left a doubt whether, if taken weight for weight, the coal ashes might not be able to support better crops than the pit-sand.*

I have recently tried an experiment bearing upon this point, with the result that no appreciable difference between the fertility of the two materials was detected. This experiment was as follows : —

Four tall, narrow glass beakers were chosen as jars in which to put the coal ashes ; and four shorter, narrow beakers were taken for the pit-sand. 700 grammes of coal ashes, such as were used in the experiments described on page 59, were placed in each of the tall jars ; and 700 grammes of pit-sand, such as was used in the earlier experiments, were placed in each of the shorter jars. Three buckwheat seeds were planted in each jar. Jars A and B sand, and A and B ashes, were watered with rain-water, and the other four jars with a solution of nitrate of lime (1 gramme to the litre), after the young plants had fairly started. It happened that one seed failed to germinate in one of the ash jars, and another in one of the sand jars that were to be watered with nitrate of lime. These dead seeds were removed, but not replaced; so that in each of the pairs of jars that were watered with the nitrate of lime, one jar carried but two plants, while the other had three; and the remark applies of course both to the ashes and the sand. The results of these trials are given in the following table : —

These figures simply re-enforce the conclusions previously arrived at (see page 66 of Vol. I.), and strengthen the conviction that, in so far as their chemical composition is concerned, the ashes of anthracite can have little, if any, significance in agriculture.

That coal ashes may serve as well as sand, or perhaps rather better than most sands, for the mechanical improvement of peaty soils, was

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* Compare Bussey Bulletin, 1. 66.

Contents of the Jars.	The crops harvested April 3, 1876, and dried at 90° to 100° C.		
	Weighed grammes	Grew to height	Had seeds.
Ashes and rain-water	0.275	4½″ 6½″ 6½″	2
„ „ „	0.220	5 6 6½	5
Sand and rain-water	0.280	4½ 5 6½	0.2 fl'rs.
„ „ „	0.320	5½ 6½ 8	5
„ Mean weight of the ash crops . .	0.248		
„ „ „ sand „ . .	0.300		
Ashes and nitrate of lime . . .	1.66 *	7 9½	22
„ „ „ „	3.810	7½ 12 14	44
Sand and nitrate of lime	1.75 *	9 10½	21
„ „ „ „	3.270	10 10½ 11½	32
„ Total weight of the two ash crops .	5.47		
„ „ „ „ sand „ . .	5.02		

urged in the former paper.   But, as several friends have suggested to me, no mention was there made of the applicability of coal ashes for the amelioration of stiff clays.   It is, however, a matter of experience †
that coal ashes are much better than sand for improving the physical condition of clay lands, because they are fine and light and friable, and because their particles, unlike those of sand, do not tend to sift out and separate themselves from the clay.   The application of coal ashes to clay lands is manifestly somewhat akin to the old methods of agriculture, known as " clay burning" and as " paring and burning," in that the action of the fire served to destroy the plasticity of a quantity of the crude clay, and that the burnt clay, when mixed with the original soil by processes of tillage, greatly improved its character.   The soil was not only less cohesive and less retentive of moisture than before, but, comparatively speaking, light and crumbly.   As was said long ago by Marshall, ‡ when describing the process of paring and burning: " Its effect in improving the contexture of strong cohesive soils has escaped general notice.   Yet how could art devise an ingredient more likely to give openness and freedom to a closely textured soil than rough, porous, unperishable ashes ? "

* Only two plants.

† Compare, for example, " New England Farmer," 1842, 21. 180, and 1845, 24. 2.

‡ Rural Economy of Yorkshire, 1796, 1. 293.

No. 15. — *The Hybridization of Lilies.* By FRANCIS PARKMAN, late Professor of Horticulture at the Bussey Institution.

TEN or twelve years ago, I began a series of experiments in hybridizing lilies, and have continued them at intervals to the present time, with results some of which are worth recording.

My first attempt was to combine the two superb Japanese lilies, L. speciosum (lancifolium) and L. auratum. The former was used as the female parent. Four or five varieties of it, varying from pure white to deep red, were brought forward in pots under glass. This was necessary, because L. speciosum does not ripen its seed in the open air, in the climate of New England. When the flowers were on the point of opening, the anthers were carefully removed from the expanding buds by means of forceps. As the pollen was entirely unripe, and as pains were taken to leave not a single anther in any of the flowers, self-impregnation was impossible. The pollen of L. auratum was then applied to the pistils, as soon as they were in condition to receive it. Impregnation took place in most cases. The seed-pods swelled, and promised an ample crop of seed; but the experiment was spoiled by the bad management of the man in charge of the greenhouse, in consequence of which the pods were attacked by mildew.

In the next year, I repeated the attempt, with the same precautions. This time the seed was successfully ripened. Being sown immediately, a portion of it germinated in the following spring, and the rest, a year later. In regard to this seed, two points were noticeable; first, it was scanty, the pods, though looking well, being in great part filled with abortive seed, or mere chaff; and, next, such good seed as there was differed in appearance from the seed of the same lily fertilized by the pollen of its own species. The latter is smooth, whereas the hybrid seed was rough and wrinkled. About fifty young seedlings resulted from it, and their appearance was very encouraging, because the stems of nearly all were mottled in a manner characteristic of L. auratum, but not of L. speciosum. Here, then, was a plain indication of the influence of the male parent. The infant bulbs were pricked out into a cold frame and left there three or four years, when, having reached the

size of a pigeon's egg, they were planted in a bed for blooming. This was in 1869. Towards midsummer, one of the young hybrids showed a large flower-bud, much like that of its male parent, L. auratum. The rest, about fifty in all, showed no buds until some time after; and when the buds at length appeared, they were precisely like those of the female parent, L. speciosum. The first bud opened on the seventh of August, and proved a magnificent flower, nine and a half inches in diameter, resembling L. auratum in fragrance and form, and the most brilliant varieties of L. speciosum in color. In the following year, it measured nearly twelve inches from tip to tip of the extended petals, and in England it has since reached fourteen inches. A colored plate of it will be found in the "Florist and Pomologist" of March, 1876, and engravings of it have appeared in the "Gardener's Chronicle" and other horticultural publications. The stock has been placed in the hands of Mr. Anthony Waterer, the distinguished nurseryman, who has given it the name of L. Parkmanni. In this one instance, the experiment had been a great success; but of the remaining fifty hybrids, not one produced a flower in the least distinguishable from that of the pure L. speciosum. The influence of the alien pollen was shown, as before noticed, in the markings of the stem, and also in a diminished power of seed-bearing; but this was all.

In the next year, wishing to see if the male parent would not make his influence appear more distinctly in the second generation, I fertilized several of these fifty hybrids, with the pollen of L. auratum, precisely as their female parent had been fertilized. The crop of seed was extremely scanty, but there was enough to produce eight or ten young bulbs. Of these, when they bloomed, one bore a flower combining the features of both parents; but, though large, it was far inferior to L. Parkmanni in form and color. The remaining flowers were not distinguishable from those of the pure L. speciosum.

While making these experiments with L. speciosum and L. auratum, I made similar attempts to produce hybrids of other lilies. In the spring of 1867, I planted twenty or more strong bulbs of L. superbum in a favorable spot, and, when they began to bloom, fertilized them with the pollen of L. speciosum, L. auratum, L. tigrinum, L. chalcedonicum, L. umbellatum, L. Thunbergianum, L. longiflorum, and L. tenuifolium. All the anthers were previously removed before ripening, by slitting the sides of the still unopened bud and extracting them

with forceps. There were no other plants of L. superbum in the garden, or in the neighborhood : so that in this case, as in the former, fertilization by the pollen of their own species could not take place. Seed-pods, large and well shaped, were formed in abundance ; but when they ripened in October, some of them contained nothing but chaff. Others had a few imperfect seeds, while others gave a fair supply of seed as good as could be desired. It was sown in pans, germinated in due time, and produced several hundred young bulbs ; but when these came into bloom, not a single flower of them all was in the least distinguishable from the pure L. superbum.   Of eight different male parents, not one had impressed his features on his hybrid offspring. Not only in their flowers, but in their leaves, stems, and bulbs, the young plants showed no variation from their maternal parent.   In the following year, I set some of them apart from the rest, and applied to them, as to their mother before them, the pollen of several species of lilies.   This time, the seeds were extremely scanty. · A few, however, were produced ; but the plants and flowers that resulted from them, were, to all appearance, L. superbum pure and simple.

Another subject of experiment was L. umbellatum, which I fertilized with the pollen of L. auratum.   Seed was produced in abundance, and the young plants began to bloom in the second year.   Many of them were not to be distinguished from the pure L. umbellatum.   Others showed unmistakable marks of their hybrid origin in the defective condition of the organs of reproduction, the anthers being abortive or wholly wanting, as were also, in a few cases, even the pistils.   In some instances, the corolla was deformed, some of the petals being absent, and others small and ill-shaped.   But while the influence of the alien pollen was shown in these defects, no features of the male parent appeared either in form, color, scent, or manner of growth.

No lily seems to offer better prospects to the hybridizer than L. longiflorum.   The species itself is not a good seed-bearer in our climate ; but one of its varieties, known as L. longiflorum Takesima, bears seed very freely.   This variety is also distinguished by superior vigor of growth, and by the dark markings of its stem.   The pure white of the large trumpet-shaped flowers seemed peculiarly fitted to receive impressions of color from an alien parent.   I therefore fertilized them with the pollen of a deep red variety of L. speciosum.   The operation was performed under glass and with the greatest care.   The seed was

abundant, and being sown immediately it all germinated in the following spring. When the flowers opened, two years later, they showed no sign whatever of the male parent. The pure white was without tint or spot; neither did the foliage and stem show the slightest trace of foreign influence. The plants were in pots. I removed a number of them to the greenhouse, and, having no pollen of L. speciosum at hand, fertilized them with that of L. auratum. Several refused to bear seed, while others produced it freely. The young plants resulting from this last experiment, bloomed in the greenhouses of the Bussey Institution in the spring of 1874. Neither L. speciosum, their grandfather, nor L. auratum, their father, had produced any effect whatever on the pure white of their petals. They showed differences of habit, among themselves, some being very tall and vigorous, and others compact and bushy, with a tendency to bloom in clusters, but these may have been mere seedling variations, with which the hybridization had nothing to do. Yet distinct evidence could be seen of the action of the alien pollen. Some of the anthers were small and abortive, and some of the pistils were imperfect; but what was more to the purpose was the changed color of many of the former. The white petals had completely resisted the foreign influence; but the yellow anthers had undergone a marked change. About half of them were turned to a chocolate color, approaching that of the anthers of the male parent, though not so deep.

I determined to try the effect of impregnation in the third generation, and applied the pollen of both L. auratum and L. speciosum to ten or twelve of the young hybrids whose organs of reproduction appeared to remain perfect. Not one of them would bear seed. In the present summer, 1877, I repeated the experiment on a larger scale, and fertilized about fifty flowers, after removing the anthers before they had ripened. Nine of these produced seed-pods, all of which were small and deformed, except two. These two contained, along with chaff, a few seeds of promising appearance. The remaining seven were full of chaff alone. The reproductive power had been nearly destroyed by hybridization repeated through three generations. What will result from the few seeds obtained, remains to be seen.

Some lilies refuse to be fertilized by the pollen of certain other lilies. Thus I have found that L. speciosum, so readily fertilized by L. auratum, will give no seed to the pollen of either L. Browni, L.

longiflorum, L. Canadense, L. tenuifolium, or L. umbellatum. Yet the converse does not always hold true, for several of these last-named species will bear seed when fertilized with the pollen of L. speciosum.

. A great number of subtile influences may modify the results of experiments in hybridization; yet those described above were so various, and extended over so many years, that the general facts to which they point may, I think, be regarded as assured. An eminent botanist has suggested to me that the tenacity with which lilies fertilized by lilies of other species retain their characteristics unchanged, may be explained by supposing that the offspring are really no hybrids at all, but results of *parthenogenesis*, that curious phenomenon which sometimes occurs in the lower orders of animals, and by which a single impregnation continues to take effect in several successive generations; in other words, that a lily of which the flower was fertilized in any one year by its own pollen may bear seed in the next year without being fertilized again. There are two good reasons for believing that parthenogenesis had nothing to do with the cases in question. In the first place, some of the lilies subjected to experiment were young plants that had never bloomed before, and consequently could not have been fertilized before. In the next place, every species fertilized by me with the pollen of another species showed, with the single exception of L. superbum, evidence of hybridity, which, though slight, was convincing. This evidence consisted in markings of the stem resembling those of the male parent, in a changed color of anthers, also resembling that of the male, and in the frequent occurrence of abortion, in both anthers and pistils, with consequent sterility. That the seedlings were really hybrids, there can be no reasonable doubt, though nobody would have suspected it from casual observation. The conclusion is that lilies, or at least the principal species of the genus, when hybridized, produce offspring which show the features of the male parent very slightly or only in exceptional cases. These exceptional cases are, nevertheless, so remarkable at times, that the rarity of their occurrence ought not to discourage the hybridist.

No. 16. — *On the Chemical Composition of the Common Field Horse-Tail or Scouring-Rush (Equisetum arvense).* By F. H. STORER, Professor of Agricultural Chemistry.

FEW plants have been more cordially detested by dairymen than the familiar horse-tail (*Equisetum arvense*), which grows abundantly in many damp places; and there would seem to be little reason for doubting that horned cattle are liable to serious injury from feeding upon it, though horses and sheep are said to be fond of the plant, and to feed upon it without injury as a general rule.

There is need enough, no doubt, of studying in detail the question, Why is it that the plant injures horned cattle? But I am in no position to undertake the solution of a problem of this kind, and have been forced to content myself for the present with a mere chemical examination of the plant in the interest of those kinds of animals which can feed upon it with impunity. I have had the curiosity, moreover, to contrast the chemical composition of the so-called fertile stems of the plant, which bear its spores or fruit, with the sterile stems, which simply bear branches.*

Considered as forage, the fertile stems are specially interesting, because of their early appearance and their brief term of life. They shoot up quickly from the root-stocks in early spring, like the asparagus sprouts, whose appearance they so much resemble; and, after bearing the spores, they shrink away, decay, and disappear, with equal or even greater rapidity; while the more familiar branching sterile stems come up in their turn from the root-stocks to replace the spore-bearing sprouts. If the fertile stems were really a useful kind of fodder, it would manifestly be important to let the pasturing animals have access to them at once as soon as they appeared, lest they should die uneaten, and so be lost altogether.

The specimens examined were obtained as follows: —

I. Fertile stems of *Equisetum arvense*, collected by my friend, Mr. Charles Wright, April 21, 1876, upon a moist railway embankment near the Bussey Institution, between Forest Hills and Mount Hope.

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* Compare Gray's "Manual of the Botany of the Northern United States," p. 585, Article *Equisetaceæ*.

The stage of development of the plants will appear from the fact that their lower spore cases were empty, while the middle ones were full, and the upper ones were still closed. A few sterile stems were beginning to show themselves when this specimen was collected. These fertile stems were succulent and tasted like raw beet-tops. The taste was not astringent. The juice was slightly acid to test-paper, and blackened the fingers when they came in contact with the knife used for cutting the plants, much as the juice of a sour apple would do.

II. Sterile stems of *Equisetum arvense*, collected on a railway embankment, May 22, 1876. These stems were from 7 to 9 or 10 inches high. Apple-trees were in blossom at the time this specimen was collected.

The results of the analyses were as follows : —

Horse-Tail.	Green Plants.		Dried at 110° C.	
	I.	II.	I.	II
	Fertile.	Sterile.	Fertile.	Sterile.
Water	87.28	85 63	——	——
Ash (free from C & CO$_2$ and Sand)	1 60	1.74	12 55	12.12
Albuminolds	1.86	3.34	14.62	23 26
Carbohydrates (including fat)	7.39	6.80	58 11	47 31
Cellulose (free from ash) .	1.87	2 49	14 72	17.31
	100.00	100.00	100 00	100.00
Dry organic matter . . .	11.12	12.63	87 45	87 88
Fat, &c. (ether-extract) .	0 34	0.76	2 68*	5.31*
Nitrogen	0.29–0.30	0.53–0 54	2 34	3 72
Crude ash	2.67†	1.99–2.00	21.00†	13.90‡
Ratio of albuminoids to carbohydrates	1:4	1:2	1:4	1:2

Of "silica and sand" together, as obtained by fusing a weighed quantity of the crude ash of the sterile stems with carbonate of soda, and subsequently separating the silica with an acid in the usual way,

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* The marked difference in the amounts of ether-extract, or "fat," found in the sterile and in the fertile stems is plainly due to the different amounts of chlorophyl contained in the two kinds of stems : the sterile stems, namely, with their abundant green branches, are rich in chlorophyl ; while the pale, fertile stalks contain only a comparatively small proportion of this substance.

† The high percentage of crude ash in the fertile stems was due to the presence of a number of grains of sands that had been caught up mechanically from the sandy soil on which they grew. It was found that 8.11% of such sand was contained in the anhydrous matter of the fertile stems.

‡ The number 13.90, given in the text, is the mean of two estimations of ash, which gave 13.87 % and 13.92 %, respectively. Other determinations of crude ash, made at a later period, gave 13.50 % and 13.55 %. The mean of the four trials was 13.70 %.

there was found an amount equal to 4.31% of the plant dried at 110°, or to 30.21% of the crude ashes of the plant. Some rough attempts were made to determine the amount of silica proper (as distinguished from sand) in the sterile stems; but the results obtained were not satisfactory. On treating ashes obtained from different portions of one and the same sample of the powdered dry plant with caustic soda, there was found, in one trial, only as much silicic acid as would amount to 1.42% of the plant dried at 110°, while in another trial there was found 2.94%, and in a third, 1.33%. In other words, there was found 10.45%, 21.70%, and 9.34%, respectively, of silicic acid in the three samples of crude ashes. It was proved, furthermore, by special qualitative trials, that the process of analysis employed was faulty, inasmuch as more or less silicic acid was dissolved out from the ashes by the caustic soda accordingly as the lye was applied in a stronger or weaker condition, and as it was made to act upon the ashes for a longer or shorter time. The behavior of the ashes in respect to caustic soda would seem to show that a considerable proportion of their silica is not free and uncombined, but held in chemical combination by some one or more of the basic ingredients of the ashes. Compare the table at end of this article. Lack of material has prevented me from studying this question, and from estimating the true amount of silica in the ashes.

The difference between the amounts of nitrogen found in the sterile and in the fertile stems is so noteworthy that, for the sake of verifying it, I have had the amount of nitrogen estimated in two other species of equisetum that happened to be at my disposal; namely, in the fertile stems of *Equisetum limosum* and in the sterile and fertile stems of *Equisetum sylvaticum*. The specimens now in question were collected by Mr. Wright, and were taken from his herbarium for analysis.

In the specimen of *Equisetum limosum*, "in fruit," collected in Dorchester, Mass., June 20, 1876, there was found, in two trials (in the plant dried at 110° C.) 1.91% and 2.16% of nitrogen, equal to 12.75% of albuminoids. In the fertile stems of *Equisetum sylvaticum*, collected May 8, 1876, on low, wet, grassy land at Forest Hills (dried at 110° C.), there was found 2.17% of nitrogen, — equal to 13.58% of albuminoids. In sterile stems of *Equisetum sylvaticum*, taken from the same parcel as the fertile stems, there was found, after drying at 110° C., 3.67% of nitrogen, — equal to 22.94% of albuminoids. These air-dried speci-

mens of equisetum gave off 8.30%, 9.89%, and 7.66% of water, respectively, on being dried at 110°.C.

The comparatively small proportion of nitrogen in the fertile stems is probably to be explained by a reference to the fact that by far the larger part of these stems consists of mere stalk, like the straw of a grain-plant. The fertile stem serves merely as a mechanical support for the spore cases ; and there is no reason to suppose that any part of it should contain much nitrogenized matter, excepting the spores themselves, which are extremely small as compared with the whole mass of the stem. The considerably larger proportion of nitrogen in the sterile stems may, perhaps, be connected with the fact that the function of the sterile stem is to accumulate nourishment to be stored in the root-stocks, whence both the fertile and the sterile stems of next year's growth are to spring.

Whatever may be the cause of the hurtfulness of the equisetum, it is evident that the plant was formerly a very serious injury to the low-lying meadows of Holland and the River Elbe, as may be seen from the following citations, or by consulting almost any of the old German treatises on husbandry. According to Nosemann,[*] who wrote a long prize essay on equisetum, and the best means of destroying it, *Equisetum arrense* is very hurtful to horned cattle in Holland, and to cows in particular. When a healthy cow in good flesh is turned into a pasture where this plant is growing, so that she may eat some of it together with the other herbage, no harm is done at first; at least, no appreciable influence is noticed during the first day or two ; but, in the course of four or five days, the bowels of the animal become very much loosened, and the yield of milk greatly diminished. This diarrhœa persists ; and both the quantity and quality of the milk continue to deteriorate ; while the cow becomes thin, flabby, and weak, and her teeth loose. But, on removing the cow to a pasture free from equisetum plants, the diarrhœa ceases after a short time ; and she soon recovers her health.

It would seem that cattle reared in a country where *Equisetum arrense* abounds, that have been accustomed to the plant from their youth, do not suffer nearly so much from it as strange cattle. But they are, nevertheless, apt to suffer somewhat from looseness of the bowels, i.e.,

[*] Beckmann's " Beytråge zur Œkonomie," u. s. w., 1788, 9. pp. 297, 319–321, 346–351, 879.

from a tendency to diarrhœa; they give less milk than cattle of similar kind kept on land free from equisetum plants; their milk yields less butter, and the butter is hard and bad.

Linnæus * has remarked upon this point, as follows : " Bidlo reports that when cows are brought from Friesland to Utrecht and Holland, where the equisetum is common, they become consumptive and die; though cows which have eaten the horse-tail from their youth up are not harmed by it."

Nosemann says further that neat-stock never prosper so well on estates where *Equisetum arvense* grows as on those that are free from it ; and that this remark is true both of animals that are pastured and of those which are fed in the stable upon hay that contains equisetum plants. At pasture, he repeats, the bowels of the cattle become so loose, and the diarrhœa which afflicts them is at last so persistent and deep-seated, that they fail either to grow, to gain flesh, or to give a proper quantity of good milk ; and, in like manner, when the animals are fed upon hay that contains equisetum plants, they suffer similar inconveniences, and their teeth become loose or drop out, so that they cannot chew their food properly. The milk given by cows thus fed, as well as the butter and cheese prepared from it, are all notably thinner, poorer, and more insipid than the normal products, or harder and of inferior appearance. The fat of horned cattle that have been pastured on equisetum land is neither agreeable nor palatable, but is disgustingly white, and has a greasy taste. Nothing is more opposed to the fattening of calves than the presence of equisetum plants in the straw with which they are bedded ; for the young animals pick out the equisetum plants, and eat them greedily, after which they are apt to become wild and to have fits, and to have so violent diarrhœa that they waste away and die.

N. Beckmann,† in like manner, reports that in Hanover, as well as in Holland, horned cattle pastured in fields infested with equisetum are apt to have diarrhœa, and to become gaunt, thin, and feeble. The cows give much less milk than they should, and what they do give is blue and of poor quality, without proper cream or rich butter. The

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* " Natur- Kunst- und Œkonomie Historie von einigen Schwedischen Provinzien," Leipzig, 1756, p. 295.

† Beckmann's " Beyträge zur Œkonomie," 1788, 9. pp., 819–823, the notes, and p. 376.

butter is insipid ·or unsavory, and is not of handsome yellow color. Even at the end of June, it is white like "straw butter."   Cattle may even die on such pastures when they have not been accustomed to them from their youth, or when they have been driven from upland pastures to the low meadows.   But horses, and some animals other than neat-cattle, take no hurt when thus transferred.   One method of checking the plant (*Equisetum arvense*) from spreading is to pasture the land during several years with horses and sheep.   In Hanover, the rent of cow-pastures is lessened about one-half, or more, by the presence of equisetum plants; and the price of hay is diminished by them in the same way.

It is to be observed that the value of Beckmann's testimony as to the actual hurtfulness of the equisetum plant is a good deal impaired by his further statement to the effect "that even cabbages and beets, or other roots that have been grown upon equisetum land, are not nearly so nourishing or so good for milch-cows as those which have been grown upon clean land, as is well known to all dwellers in the Hanoverian marshes.   The milk obtained from such fodder is almost as blue and thin, and the butter as pale and unsavory, as if the cows had been eating grass or hay that was mixed with equisetum plants."   The inference to be drawn from this statement is, that the animals fed with the watery bog-plants were insufficiently nourished.   It is probable that there was considerably less dry matter in a given volume of the vegetables in question than in those grown upon dry land; and not unlikely that the cattle got for their rations one and the same bulk of the fodder, no matter where it was grown.

There is a good deal of testimony upon record to the effect that *Equisetum arvense* may be eaten by horses and sheep, not only with impunity, but with advantage.   Thus, Braun [*] has stated that hay, which contains so much equisetum that it would be very injurious to horned cattle is not only harmless as regards horses, but is excellent fodder for them.   A Hanoverian farmer, who was noted for his knowledge of horses and his skill in rearing them, esteemed hay that was charged with equisetum plants to be excellent fodder for these animals.   He was accustomed to buy such hay in preference to the usual kind. Switzer [†] reports that the plant is sometimes eaten by horses in prefer-

[*] Beckmann's ". Beyträge zur Œkonomie," u. s. w., 1783, 9., pp. 880, 882.
[†] Beckmann's " Beyträge," 9., pp. 359, 861.

ence to the adjacent grass; and Braun, like Beckmann, says that it may be destroyed by long-continued pasturing with horses. Sprengel [*] reports that horses and sheep are fond of all sorts of *Equisetaceæ*, and eat them without detriment; whereas neat-cattle, when driven by hunger to eat them, are liable to get diarrhœa, or even finally to die.

In opposition to the foregoing statements, and to many others of like import that might be cited, I find two statements to the effect that equisetum plants may sometimes be injurious even to horses. The botanist, Nuttall,[†] who observed *Equisetum hyemale* (*i.e.*, the true scouring rush) growing abundantly on the banks of the Missouri River, below the Platte, where it was known as "rushes," says that it is found to be injurious to horses who feed upon it for any considerable length of time. On the other hand, Mr. W. H. White,[‡] of Connecticut, is said to have published, in the "New England Homestead" for 1873, an account of the poisoning of horses by *Equisetum arvense*. Since I have no access to the paper in question, and have never seen a detailed account of Mr. White's statement, I am unable to form any opinion as to its importance.

Nosemann,[§] in his prize essay, ascribes the hurtful effects of the equisetum to its astringency; and he dwells upon the fact that the juice of the plant gives a black coloration when mixed with iron-vitriol. It is true, as has been already stated on page 167, that the juice of the plant blackens the knives with which it is cut; but this blackening is no more pronounced than that caused by many apples and by a great variety of other harmless fruits and vegetables. It would seem much more probable that the injurious action of the equisetum plant is purely mechanical, and that the intestines of the animals are irritated by its harsh, rough stalks and leaves. The rough, silicious character of the outer surfaces of the various kinds of equisetum is well known. One species of the plant, the scouring-rush proper (*Equisetum hyemale*), was formerly much used for polishing wood, horn, ivory, stone, and metal. It was imported into England from Holland, under the name of Dutch rushes for this purpose; and was not only used by whitesmiths, cab-

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[*] Erdmann's "Journal für tech. und œkonom. Chemie," 1829, **5.** 44.

[†] Cited in Gouverneur Emerson's edition of C. W. Johnson's "Farmers' and Planters' Encyclopædia," New York, 1855, p. 647.

[‡] As cited in "American Agriculturist," June, 1877, p. 9.

[§] Beckmann's "Beytrâge," **9.** 348.

inet-makers, and comb-makers, but was in demand in the kitchen also, for scouring pewter and wooden ware.[*]

It is not merely the absolute amount of silica in the equisetum plants that must be considered, but the position of the silica at or near the external surface of the plant, and the form in which the silica has been deposited in the plant-cells.[†]   According to Sachs,[‡] the cells of the epidermis or external coating of the equisetum plant, even those which form the breathing-pores, are very much silicified upon their outer walls; and there are very often on the outer surfaces of the cells protuberances of various forms, which are likewise very strongly silicified. These protuberances are in the forms of granules, bunches, rosettes, rings, and tongues, of transverse bands, and of teeth or spines.   Upon the cells of the breathing-pores, they take the form of bands or ridges perpendicular to the orifice of the pore.

So too, according to H. Rose,[§] when equisetum stalks are calcined, there remains a highly silicious ash, which is seen under the microscope to retain perfectly the form of the original unburned stem.

The following list comprises the amounts of ash and of silica in the ash that have been found in equisetum plants by various observers: —

Braconnot [‖] found in dried sterile stems of *Equisetum arvense* 13.84% of crude ash, and in this ash he found 45.97% of silica; in *E. fluviatile* he found 23.61% of ash, and, in the ash, 50.83% of silica; in *E. limosum* he found 15.50% of ash, and in the ash 41.94% of silica; in *Equisetum hyemale* he found 11.81% of ash,[¶] and, in the ash, 74.09% of silica.   These numbers correspond with the following percentages of silica in the dry plants themselves; viz., 6.38% of silica in *E. arvense*, 12% in *E. fluviatile*, 6.5% in *E. limosum*, and 8.75% in *E. hyemale*.

Witting [**] found in fresh sterile stalks of *E. arvense* 78.45% of water and 4.07% of crude ash (*i.e.*, 18.89% of ash in the plant dried

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[*] Loudon "Encyclopædia of Plants."   Compare Braconnot, "Annales de Chimie et de Physique," 1828, **39**. pp. 5, 22.

[†] Compare Johnson's "How Crops Grow," New York, 1868, p. 185.

[‡] "Traité de Botanique," Paris, 1874, p. 493.

[§] Poggendorff's "Annalen," 1849, **76**. 359.

[‖] "Annales de Chimie et de Physique," 1828, **39**. 24.

[¶] Hawes (" American Journal of Science," 1874, **7**. 585) found 11.70% and 11.82% of ash in dried plants of *Equisetum hyemale*, collected near New Haven, Conn.

[**] "Journal für praktische Chemie," 1856, **69**. 176.

at 100° C.) and in this ash he found 41.40% of silica, besides an abundance of potash, lime, phosphoric acid, &c. In *Equisetum Telmateja*, dried at 100° C., he found 28.57% of ash, and in the ash 66.15% of silica. These numbers correspond to 7.82% of silica in the plant itself of *E. arvense*, and to 18.90% in *E. Telmateja*, both dried at 100°.

A student in Wicke's laboratory, Brock,[*] is said to have found 83.16% of silica in the ash of *E. hyemale*.

Some determinations of silica by Struve,[†] which have been cited here and there as illustrating the large amount of silica (95 to 97.50% !) in equisetum ash, have really no such meaning; since the analyses were made neither upon equisetum plants nor upon their natural ashes, but upon certain products that had been prepared from the ashes by leaching them with water and acids.

On contrasting the amounts of ashes and of silica that have been found in the equisetums with the amounts contained in the straw of some of the cereal grains, it will be seen that it is the large amount of ash in the equisetum plants, rather than the proportion of silica in that ash, which makes the quantity of silica in the plant itself so much larger than it is in the straws. More than 70% of silica has often been found in the ash of the straw of winter wheat, for example; and from 60 to 65% of silica is not infrequently found in the ashes of rye-straw. But in dry wheat-straw containing 5% of ash, of which 70% was silica, there would be only 3.50% of silica in the straw; and in rye-straw containing 5% of ash, of which 65% was silica, there would be 3.25% of silica in the straw: whereas, when Braconnot found 45.99%, and Witting 41% of silica in the ash of *Equisetum arvense*, they found, respectively, 13.84% and 18.89% of ashes in the dry plants, and these numbers are equivalent to 6.38% and 7.82% of silica in the plants, or twice as much as in the straws above cited. In the great water horse-tail of Europe, *E. fluviatile*, there has been found as much as 12 lbs. of silica in 100 lbs. of the dry plant; and in another great European horse-tail (*E. Telmateja*), 18.9 lbs. of silica to 100 lbs. of the plant.

For the sake of controlling the estimations of silicic acid in *E. arvense* that have been given above on page 168, I procured a fair sample

* " Annalen der Chemie und Pharmacie," 1856, **97**. 349.
† Poggendorff's " Annalen," 1849, **76**. 359.

of rye-straw, taken at random from the Boston market, and had the amounts of crude ash, total silica, and silica soluble in caustic soda determined in the same ways that these substances had been previously estimated in the ash of *E. arvense*.   The results of this comparison are as follows : —

Per cent of crude ash in rye-straw dried at 110° 4.14–4.86
    ,,   ,,   ,,   sterile stems of *E. arvense* dried at
        110° 13.70–13.90

Per cent of total silica in ash of rye-straw 39.72
    ,,   ,,   ,,   *E. arvense* 30.21

Per cent of SiO$_2$ dissolved by soda from ash of rye-straw .   30.42
    ,,   ,,   ,,   ,,   ,,   *E. arvense* 9.34–10.45–21.70

Per cent of total silica in the rye-straw itself, dried at 110°   1.93
    ,,   ,,   ,,   *E. arvense* ,,   ,,   4.31

Per cent of soluble SiO$_2$ in the rye-straw ,,   ,,   1.26
    ,,   ,,   *E. arvense*   ,,   ,,   1.33–1.42–2.94

I am indebted to my assistant, Mr. D. S. Lewis, for most of the analytical labor in this research.

No. 17. — *Results of a Chemical Examination of the Shells of Crabs and Lobsters, and of those of Oysters, Clams, Mussels, and other Shell-fish.* By F. H. STORER, Professor of Agricultural Chemistry.

THE chemical composition of most of the sea-weeds that are employed as manures has been studied with a good deal of care by European chemists; and it might be said of sea-shells also, that a considerable amount of information as to their composition, that would be of interest to farmers, has been gained, and may be found recorded in one place and another.   But, in so far as I am aware, no special examination of the shells of crustaceans and mollusks, from the farmer's point of view, has hitherto been undertaken.

It was my intention to make good this deficiency, and to determine the fertilizing constituents of all the shells of our sea-coast that are large enough or common enough to claim the attention of the farmers who have access to such materials.   I had intended, furthermore, to examine the various kinds of quick-lime, obtained from limestones, that are merchantable in this vicinity, and to contrast their composition with that of the shells and of the "shell-lime" that is prepared from them.   Circumstances have prevented me from carrying out this idea; and the following statement is consequently far less complete than I had hoped to make it.   But it is nevertheless true that the results of the research are correct in so far as they go, and that they add something to what was known before of the matters to which they relate.

The substances examined are described in the following paragraphs. I would here express my thanks to Mr. Vinal N. Edwards, of Wood's Hole, Massachusetts, for his kindness in procuring for me abundant supplies of most of the materials enumerated, as well as a number of other specimens that I have been forced to leave untouched.

I. Shells of the common Lobster (*Homarus Americanus*, Milne-Edwards), obtained, after the lobsters had been boiled, from fish-dealers in Boston and Cambridge.   A considerable quantity of shells taken from the bodies of lobsters, but not from their claws or legs, were reduced to powder, and passed through a sieve having meshes of 1 mm. diameter, in order to obtain a fair sample for the analysis.

II. Dry shells of the common Crab (*Lupa dicantha*, Milne-Edwards) as picked up on the sea-shore near Wood's Hole, Mass. This sample and all that follow were prepared for analysis by powdering and sifting the shells as in No. I.

III. Dry shells of the Horse-shoe or King-Crab (*Limulus Americanus*) picked up on the sea-shore near Wood's Hole. Shells from the backs and legs of several of the crabs were freed as completely as possible from adhering remnants of flesh, and were then ground to powder and sifted as in No. I.

IV. Shells of the common Oyster (*Ostrea Virginiana*, Lister), obtained in the fresh condition at a Boston market. The shells were carefully cleaned, washed, and dried A pound and a quarter of the air-dried shells were powdered and sifted in order to obtain a sample for analysis.

V. Shells of the common Clam (*Mya arenaria*), obtained in the fresh condition from a fish-dealer in Cambridge.

VI. Shells of the common Quahaug or Hard clam (*Venus mercenaria*) from Wood's Hole, Mass.

VII. Shells of the Broad Sea-clam or Hen-clam (*Mactra gigantea*) as picked up dead and blanched, upon the beach at Manchester, Mass.

VIII. Shells of the common Small Mussel (*Mytilus borealis*, Lam.) from the sea-shore at Wood's Hole. These shells had been washed clean by the sea-water *i.e.* they contained no trace of the animals to which they had belonged, but they were not blanched.

IX. Shells of the Large or Horse-mussel (*Mytilus modiolus*, Turton) from the sea-shore at Wood's Hole. Not a few of these shells were somewhat worn and "worm-eaten."

X. Shells of the common Scallop of Cape Cod (*Pecten concentricus*, Say), from Wood's Hole.

XI. Shells of the Sea-snail *Natica heros* from Wood's Hole.

As is well known, the incombustible portion of all such shells as have been mentioned above consists chiefly of carbonate of lime. This ingredient is common to all the shells, and they contain such an overwhelming proportion of it that, from the agricultural point of view, there would not be the least interest in determining the precise amount of this constituent in any one case. I have confined my inquiries therefore to the estimation of the amounts of phosphoric acid, potash, and nitrogen as set forth in the following table, and in two or three cases the amount of magnesia also.

TABLE OF THE PERCENTAGE COMPOSITION OF THE SHELLS OF LOBSTERS, CRABS, OYSTERS, CLAMS, MUSSELS, ETC.

(N.B. — *The powdered shells were all thoroughly dried at 105° to 110° C. before analysis.*)[*]

Per cent of	I LOBSTER.	II CRAB.	III KING-CRAB.	IV OYSTER.	V CLAM.	VI QUAHAUG.	VII HEN CLAM.	VIII MUSSEL.	IX HORSE MUSSEL.	X SCALLOP.	XI NATICA.
Crude Ash . . .	45.57	65.25	5.92 — 6.19	98.37	97.74	96.89	98.22	96.88	97.41	97.59	96.77
Loss by ignition . .	54.43	34.75	94.08 — 93.81	1.63	2.26	3.11	1.78	3.12	2.59	2.41	3.23
Silica and Sand . .	0.1215	0.9447	4.86	0.4239	0.0629	0.0877	0.0661	0.0612	0.1684	0.0793	0.3236
Phosphoric Acid . .	3.1190	3.5519	0.2814	0.0649	0.0147	0.0180	0.0248	0.0296	0.0310	0.0613	0.0169
Potash . . .	0.2616	0.2193	0.0625	0.0398	0.0424	0.0371	0.0227	0.0308	0.0215	0.0399	0.0458
Nitrogen . . { I	3.927	1.937	12.356	0.0804	0.0465	0.0107	0.0169	0.2824	0.0098	none	none
II	4.030	1.962	12.750	0.0663	0.0604	0.0154	0.0265	0.2830	0.0263	0.0047	none

[*] The amount of moisture lost on heating the air-dried shells to 105° or 110° was determined in several instances, with the following results: Lobster-shell lost 4.44%, and oyster-shell in two trials 4.27% to 4.47%, while the clam-shell lost only 0.31% of its weight.

Note. With regard to this table, it should be said that the phosphoric acid and potash, and the magnesia also (see page 179), were estimated with the utmost care in each instance, and that the results which relate to these constituents may be accepted without reservation. As regards the nitrogen in the sea-shells, however, the figures given in the table may perhaps be a little lower than the truth; since this element was determined in the powdered shells by the soda-lime process, which is not specially well adapted for use where the nitrogenous organic matter is encrusted with a stony concretion as in the shells. Since it was apparent that the proportion of nitrogen in the sea-shells is very small in any event, I have taken no particular pains to estimate the amount precisely, except in the single instance of the oyster, as will be described below. The estimations of "Silica and Sand," though obtained incidentally, as it were, are accurate.

The items "Ash" and "Loss by ignition," depend upon rough estimations of the matter that was driven off on igniting the several shells after they had been dried at 105° to 110° C., and are to be regarded as mere approximations to the truth. It is difficult on the one hand to burn off all the organic matter of the shells because of the calcareous matter that envelope it, and on the other hand it is easy to expel some carbonic acid during the ignition of the carbonate of lime. In the experiments here recorded, no special care was taken to guard against either of these contingencies. The shells were ignited solely for the purpose of fitting them for the estimation of potash, as will be explained on a subsequent page; and the samples were weighed before and after igniting them, merely for the sake of getting a general idea of the amount of organic matter in the shells. It will be seen from the table that, while the sea-shells proper lose a very small proportion of their weight under these conditions, the lobster and crab shells lose a great deal.

The merest glance at the table will be sufficient to show that, beside carbonate of lime, the amounts of fertilizing substances in the sea-shells proper are extremely small. The shells of the lobster and of the crabs, on the other hand, are not only very much richer in phosphoric acid, potash (magnesia), and nitrogen than the sea-shells, but they contain enough of these constituents to make them worthy of some attention on the part of those farmers who can procure such shells with very little labor or expense.

The ashes (6.05% as the mean of two experiments) left on burning the horse-shoe or king-crab contain, beside much carbonate of lime, $4\frac{1}{2}$% of phosphoric acid and 1.16% of potash. The results of some analyses by C. Schmidt,[*] of shells of the lobster, craw-fish, and squill or mantis-crab, may be cited in this connection. It is unfortunate that the data given by Schmidt are insufficient to permit a close comparison of his results either with my own, as given in the table above, or with those obtained by other chemists, that are given in the table on page 190. Schmidt found in 100 parts of the shell of the

	Lobster, *Astacus marinus.*	Craw-fish, *Astacus fluviatilis.*	Squill, *Squilla mantis.*
Chitin	22.94	46.73	62.84
Lime salts	77.06	53.27	37.17
[Nitrogen in this chitin	1.50	3.024	4.267]

In 100 parts of the ash obtained on calcining the shells, he found

Phosphate of lime [†] . .	12.06	13.17	47.52
Carbonate of lime . .	87.94	86.83	52.48
[Phosphoric acid in this phosphate of lime .	5.52	6.03	21.77]

In the concretions, found in the craw-fish, that are known as crab's eyes or crabs' stone, Dulk [‡] found 15.76% of organic matter, 8.69% of phosphoric acid, 0.22% of magnesia, and 63.16% carbonate of lime. For an earlier analysis of these concretions by Merat-Guillot, see "Annales de Chimie," **34**. 71. Analyses of two crabs' stones, dried at 110° C. by Weiske,[§] indicated 14.44 and 15.08% of organic matter (chitin), 85.56 and 84.92% of mineral matters, 55.72 and 55.42% of lime, 10.73 and 11.28% of phosphoric acid, 31.09% and 30.60% of carbonic acid, and traces of magnesia.

Beside the substances enumerated in my table, magnesia, also, was specially determined in three instances; viz., in the shell of the lobster, the oyster, and the clam, as follows: The lobster-shell, dried at 105°

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[*] Annalen der Chemie und Pharmacie, 1845, **54**. 303.

[†] Together with some phosphate of magnesia.

[‡] "Journal für praktische Chemie," **3**. 313.

[§] "Die landwirthschaftlichen Versuchs-Stationen," 1877, **20**. 45.

@ 110°, contained 1.5665% of magnesia ; or, when taken in the air-dried state, it contained 1.497%.   The oyster-shell contained 0.2779% of magnesia, when dried at 105° @ 110°, or 0.266% when air-dried. The clam-shell contained 0.0329% of magnesia when dried at 105° @ 110°, or 0.0328% when air-dried.

As regards the magnesia in sea-shells, these results do but re-enforce a mass of evidence that had been accumulated by previous observers. Schlossberger,[*] for example, found " barely 0.3 @ 0.5% of magnesia in oyster-shells dried at 120°.''   Forchhammer [†] had previously insisted upon the small proportion of magnesia that is found in shells and in most corals and in most of the chalks and limestones that have been formed directly from such shells and corals.   Besides analyzing several chalks and lime-stones which contained but little magnesia, he examined a number of shells and corals, with the following results.   He found in

	Carbonate of magne-sia, MgO, CO$_2$.	Or, magnesia, MgO.
Terebratula psittacea	0.457%	0.218%
Modiolus papuana	0.705	0.336
Pinna nigra, from the Red Sea .	1.000	0.476
Tritonium antiquum	0.486	0.231
Cerithium telescopium	0.189	0.090
Nautilus Pompilius	0.118	0.058
Ossa Sepiae	0.401	0.191
Astræa cellulosa	0.542	0.259
Myriazoon truncatum	0.445	0.212
Helenopora abrotanoides . . .	0.352	0.168
Eschara foliacea	0.146	0.070
Frondipora reticulata	0.596	0.284
Corallium nobile	2.132	1.015
Isis hippuris	6.362	3.028
Serpula Sp., from Mediterranean .	7.644	3.640
Serpula triquetra, from North Sea	4.455	2.121
Serpula filograna, from North Sea	1.349	0.642

The first three shells in the foregoing list are bivalve; the next two are univalve; nautilus and ossa belong to the class of cephalopods; and the others are corals, excepting the last three serpulas, which are sea-worms that exude a calcareous secretion to form a long, twisted tube, in which the animal resides.

It will be seen that, excepting Corallium and Isis, among the corals, and the worm Serpula, the amount of magnesia in the shells seldom ex-ceeds 0.3%.

* " Annalen der Chemie und Pharmacie," 1856, **98.** 101.
† " Journal für praktische Chemie," 1850, **49.** 52.

Silliman * found less than one per cent of magnesia in his analyses of recent corals. Phipson † found 0.13% of magnesia in the shells of the common cockle of Europe.

There are several noteworthy differences as to the proportion of nitrogen contained in the different shells, which undoubtedly depend not so much upon differences in the amounts of organic matter in the different shells as upon the presence in the organic matter of a larger or smaller proportion of nitrogenized compounds. It may possibly be true, moreover, that different kinds of nitrogenized compounds occur in different kinds of shells. A certain amount of attention has been called to this question already by the conflicting results obtained by various chemists who have examined the organic matter in shells; and it is to be understood that the results given above do but emphasize peculiarities which had been noticed before. Thus, in the case of the fresh shells of the small mussel, No. viii. of the table, it will be seen that the proportion of nitrogen is unusually high, both when the nitrogen is referred to the dry shells, of which it constitutes 0.28%, and when it is referred to the organic matter ("loss by ignition") in the shell, of which the nitrogen constitutes a little more than 9%. It would seem to be evident, on comparing this result with those obtained from the other sea-shells, that the mussel-shell must contain an unusually large proportion of the highly nitrogenized substance known as conchiolin, which has been found by Fremy ‡ and Schlossberger § in some kinds of sea-shells and in coral. The organic matter in the oyster-shell, on the other hand, though by no means entirely free from nitrogen, evidently contains comparatively little conchiolin.

Since the percentage of nitrogen (0.083) in the dried oyster-shell of the table differs very decidedly from the amount given by Boussingault and Payen ‖ some years since, I have been at pains to verify the observation, and have had other analyses made for the purpose of determining the amount of organic matter in the oyster-shell, and the nitrogen in this organic matter, as well as new estimations of nitrogen in the shell itself, by a process somewhat different from that

* "American Journal of Science," 1848, 6. 269.
† "Report British Association," 1859, p. 77.
‡ "Annales de Chimie et de Physique," 1855, 43. 96.
§ "Annalen der Chemie und Pharmacie," 1856, 98. 103.
‖ "Annales de Chimie et de Physique," 1841, 3. 103. They found 0.40 % of nitrogen in the dried shell, or 0.82 % in the fresh, undried shell.

employed for the analyses recorded in the table. The methods and results were as follows : —

A weighed quantity of powdered oyster-shells was digested with cold, highly-dilute chlorhydric acid until the whole of the carbonate of lime was dissolved ; the insoluble organic matter was washed, dried, and weighed ; and the amount of nitrogen in this organic matter was determined by combustion with soda-lime. In two experiments, there were found 1.04% and 1.30% of organic matter, respectively. The nitrogen amounted to 6.37% of the dry organic matter, or to 0.066% and 0.069% of the original dry shell.

In order to avoid the risk (already noticed in the note on page 178) of failing to get the whole of the nitrogen when the powdered shells are ignited with soda-lime directly, weighed quantities of powdered oyster-shell were treated with acid enough to completely decompose the lime-salt, and the excess of acid was neutralized with soda-lime. The dry powder thus obtained was mixed with more soda-lime, and the nitrogen estimated by combustion of the mixture in the usual way. By operating in this manner, there was found in the dry oyster-shell 0.12% of nitrogen in one instance, and 0.092% in a second trial. All of which goes to show that the amount of nitrogen in the oyster-shells examined in this laboratory is really very small, as was stated in the table, and by no means so large as was to have been inferred from the statement of Boussingault and Payen.

Other experiments still were made, to determine, more precisely than had been done before, how much the dry powdered shells lost when their organic matter was destroyed by the method of ignition. To this end, two separate portions of the dried powder were thoroughly roasted, the residues were moistened with a solution of carbonate of ammonia, in order to replace any carbonic acid that might have been driven off from the lime during the calcination, and then dried and weighed ; and the process was repeated until the weight of the matter in the crucible remained constant. There was found in this way, in one not very satisfactory experiment, 2.83%, and, in another and better trial, 3.61% of " loss by ignition." It is hard to believe, however, that the whole of this loss by ignition is really organic matter. Probably a considerable part of the loss is mere water, that was retained so forcibly by the shell that it failed of being driven off at the temperature of 110°. It will be noticed that the amount of the loss by ignition is very much larger than the amount of organic matter that was found directly by treating the shell with an acid, as was just now stated ; and the discordance between the two results is perhaps even more

strongly marked on referring to the amounts of nitrogen that were found in the shell and in the organic matter that was separated from the shell. If, for example, the whole of the loss by ignition be regarded as organic matter, and the highest proportion of nitrogen (0.12%) that was found in the dried shell be referred to this supposed organic matter (3.61%), it would appear that the organic matter of the shell contained only $3\frac{1}{3}$% of nitrogen; whereas the organic matter actually separated from the shell by dissolving the lime-salt in acid contained $6\frac{1}{3}$% of nitrogen. Nevertheless, it is not wholly improbable that a good part of the organic matter in the oyster-shell is soluble in dilute acids, and that the observed differences between the "loss by ignition " and the organic matter, separated by means of an acid, are to be explained in this sense. Schlossberger [*] did in fact long ago resort to this explanation. On noticing that the amount of loss, when oyster-shells were incinerated, was often a quarter larger than the amount of organic matters obtained by dissolving the lime-salt in an acid, and collecting the undissolved portion of the shell, he concluded that chlorhydric acid, even when very highly diluted, must dissolve a considerable proportion of the organic matter of the oyster-shell.

It will be noticed that the percentage of nitrogen (6.37) found in the organic matter that was left when the oyster-shell was treated with an excess of dilute acid is remarkably like the amount (6.44%) that is contained in chitin. But this coincidence is to be regarded as accidental merely. Chitin, though abundant in the shells of lobsters and crabs, has never been found in sea-shells. Moreover, one of the most important steps in the preparation of chitin is to boil with strong potash-lye the crude organic matter that is left when the carbonate of lime of the lobster-shell has all been dissolved out by means of acids. The hot alkali dissolves (various ?) nitrogenized matters that were mixed with the chitin, and leaves the latter free. So, too, when the organic matter that is left by the action of acids upon sea-shells is boiled with potash-lye, a very considerable proportion of it dissolves, and conchiolin is left free. With regard to the special instance now under consideration, Schlossberger [*] insisted long ago that the organic matter of the oyster-shell, as left after the lime-salt has been removed by a weak acid, consists of at least two different substances which may be roughly separated from one another by elutriation. One is a tough, brown, somewhat transparent, membrane, and the other consists of white or gray membranous flocks of very different structure from the brown matter. The gray flocks dissolve well-nigh completely on being boiled in potash-lye; and the brown membrane, which is very much more abundant than the gray flocculent matter, gives up 46% of its weight when boiled with the potash. But the residue, insoluble in potash, left after the boiling, was found to contain from 16 to 16.7% of nitrogen; that is to say, very nearly the amount that is contained in conchiolin.

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[*] " Annalen der Chemie und Pharmacie," 1856, **98.** 108.

In conchiolin, obtained from the horny axis of a gorgonia coral, Fremy[*] found 16.8% of nitrogen, and in conchiolin from sea-shells, 17.5%.

There is one item in the table which is truly remarkable, and that is the large proportion of nitrogen [†] in the shell of the horseshoe or king-crab, — a result which is almost as eccentric and extraordinary as the king-crab itself is among crustaceans.

It would be interesting to study this nitrogenous matter, with the view of determining wherein it may differ from the chitin that is found in the shells of the lobster and crab, and whether or not it is allied to the ossein of bone or the conchiolin of sea-shells.   But I am at present unable to undertake this inquiry.   In this connection, it is noteworthy that C. Schmidt,[‡] on examining the leathery or membranous outer covering of an ascidian mollusk (*Cynthia mammillaris*), which consisted almost entirely of water, and contained no more than 1.07% of dry

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[*] "Annales de Chimie et de Physique," 1855, **43.** 97.   Silliman (Liebig and Kopp's "Jahresbericht der Chemie," 1850, **3.** 813) found about 6 % of ashes in the horny stem of *Gorgonia antipathes* from Bermuda.

[†] In order to be perfectly sure upon this point, and for the sake of determining whether any one part of the shell of the king-crab contains a larger proportion of nitrogen than the other portions, I have had made several new estimations of the amount of nitrogen in different parts of the shell of one large individual king-crab, as follows : It will be remembered that the figures given in the large table relate to a mixture of material that was obtained by powdering the shells of several crabs of different sizes.   It is to be observed, moreover, that the results recorded in this note were obtained by another analyst, who had had nothing to do with the work given in the large table.

A. In a sample of shell taken from the centre of the anterior section of the upper covering of a large king-crab, and dried at 108° to 110°, there was found 10.94 %, and 10.96 % of nitrogen, in two separate trials.   Since the air-dried shell lost 9.75 % of moisture in the process of further drying, the above figures correspond to 9.87 % and 9.89 % of nitrogen in the air-dried shell.

B. Shell from the posterior section of the old king-crab, dried at 108° to 110°, gave 13.63 % and 13.87 % of nitrogen.   The air-dried shell lost 8.46 % of moisture when dried as above stated.

C. Shell from the posterior section of a young king-crab, dried at 108° to 110°, gave 13.35 % of nitrogen ; and the air-dried shell lost 11.10 % of moisture in the process of drying.   The air-dried shell contained 11.87 % of nitrogen.

D. Air-dried shells of the legs of the old king-crab lost 6.86 % of moisture on being dried at 108° to 110°.   There was found 11.09 %, 11.50 %, and 12.14 % of nitrogen in the thoroughly-dried shells, or 10.33 %, 10.71 %, and 11.31 % in the air-dried shell.

The mean of all these estimations, equal 12.18 % of nitrogen in mixed shell of the king-crab dried at 108° to 110°, differs but little from the numbers given in the large table.

[‡] "Annalen der Chemie und Pharmacie," 1845, **54.** 318.

matter, found that the organic matter was of the same composition as cellulose, and that it contained no nitrogen whatsoever.

The agricultural value of the nitrogen in the shells is unknown. It is probably not very great, as compared with the value of the nitrogen in guano, nitrates, and ammonium salts. Whatever the value may be, it can only be determined by experiments which shall test directly the influence of this form of nitrogenous matter upon the growth of vegetation. It is to be remembered, in this connection, that, practically, the crabs or horseshoes, and in many cases the shell-fish also,* which the farmer brings to his land, usually contain more or less flesh adhering to them, sometimes in the fresh condition, and sometimes dry; and that this flesh might in some cases supply to the land a considerable amount of nitrogen of approved quality. Nevertheless, it is plain that, as the general rule, sea-shells must be regarded simply as a calcareous manure, that may be used with advantage in certain localities instead of lime or marl. The other fertilizing matters, beside carbonate of lime, which are contained in the shells have undoubtedly a certain small value of their own which tends to enhance the worth of the shells somewhat; but the amounts of these supplementary matters are so small that very little importance can be attached to them. In case, indeed, a farmer had to choose between lime from sea-shells, and that from a lime-stone proper, the known presence of the small quantities of phosphoric acid, &c., in the shells would naturally lead him — other things being equal — to prefer the shell-lime, unless he had some evidence that the other form of lime accessible to him contained as

* This remark applies with especial force to the so-called mussel-bed, which is often used as a fertilizer, with great advantage, upon the New England coast, as may be seen in several of the Reports of the State Boards of Agriculture of Maine and Connecticut. The "mussel-bed" consists of impacted masses of living mussels dug at low-water from the large beds in which this kind of shell-fish habitually congregates. Its efficacy as a manure may manifestly depend upon either one or both of two causes. The flesh of the mussel is a nitrogenous manure, of quick action; and to it is to be attributed the rapid and energetic effects which have often been noticed when land has been dressed with this fertilizer. On the other hand, the delicate, friable shells of the mussel undoubtedly often play the part of a calcareous manure, such as marl or leached ashes; and to this cause the well-known lasting or durable effect of the "mussel-bed" must be referred. The fact that mussel-bed has sometimes been found specially useful upon clayey soils may be due in part to an improvement in the texture of the clay, brought about by the mere loosening or mechanical action of the broken shells. Compare Wilda's "Landwirthschaftliches Centralblatt," 1858, 6. (ii.) 32.

much or more of these supplementary fertilizing constituents.   Practically, shell-lime, where it is to be had at all, usually costs less than the other forms of lime; and it is probable that it is actually a little better for agricultural purposes than stone-lime, such as is obtainable hereabouts, because of the small quantities of fertilizing matters, other than lime, that are contained in it.

The advantage to be derived from using sea-shells in a finely powdered condition, rather than in their natural form, has often been noticed.   But it is to be observed, in this regard, that the smallness of the proportion of nitrogen in sea-shells teaches very emphatically that there is nothing to be gained by pulverizing the shells with mechanical appliances, instead of by means of fire; or, rather, that no useful constituent will be lost by resorting to the cheaper device of burning the shells to quick-lime, as a means of reducing them to powder.   When the quick-lime is slaked with a small quantity of water, it falls, of course, to a fine dust; and the process of burning has the further merit of reducing the weight of the shells, and the cost of transporting the lime in them, nearly one-half.

It is to be observed, furthermore, that the organic matter in unburnt oyster-shell may do actual harm in that it commonly tends to protect the calcareous matter from the solvent action of water, carbonic-acid water, and the other chemical agents that exist in the soil.   Thus, Bischof [*] found not only that the membranes between which the carbonate of lime in oyster-shells is enclosed protect the lime-salt in a high degree against the action of dilute muriatic acid, but that fragments of oyster-shell are much less easily soluble than chalk or limestone in carbonic-acid water; and that the interior pearly part of the shell is less soluble than the outer portion.

On exposing fresh oyster-shell to the action of carbonic acid in water for twenty-four hours, it was found that 1,000 parts of water saturated with carbonic acid had dissolved of

Lamina from the interior of the shells 0.028
The same, powdered 0.160
Chips from the exterior 0.070

According to Bischof, the laminæ from the interior of the shells require for solution thirty-six times as much carbonic acid water as chalk, and one hundred times as much as precipitated carbonate of lime; the chips from the exterior fourteen times as much as chalk, and forty times as much as the artificial carbonate.   That the crystalline condition of carbonate of

[*] In his "Elements of Chemical and Physical Geology."   London: 1854, 1. pp. 181, 182.

lime has no such marked influence upon its solubility as the presence of the enveloping membrane of organic matter in the shells was shown by the fact that 1,000 parts of water, saturated with carbonic acid, dissolved 0.42 parts of powdered calc-spar; *i.e.*, three times as much as was dissolved from the powdered pearly portion of the shell. Quenstedt had previously remarked that shells taken from heaps dating from prehistoric times effervesce more strongly than fresh shells when treated with dilute muriatic acid; and that, while the fresh shells yield with the acid a gelatinous mass, having the form of the shell, the old shells leave no such gelatinous residue.

In this connection, some experiments of Sorby * have a certain interest. They were made for the purpose of determining why it is that several kinds of shells, such as those of oysters or limpets, are more frequently met with in a fossil state than other kinds, such as cockle-shells, for example. According to Sorby, it is a fact of common observation that certain kinds of fossil-shells are found to have lost their organic structure, or to have been entirely removed from the same beds in which other kinds remain almost in their original state. Most univalve shells — such bivalve shells as *Trigoniæ*, and the inner layer of *Aviculæ* and *Spondyli* — are often altered or removed though their outer layer, and the entire shells of *Ostreæ* and *Brachiopoda*, are well preserved. He finds by experiment that this difference in durability is due to original differences in the condition of the calcareous matter of the shells; and that, other conditions being the same, shells which were composed of calcite are preserved, while those composed of arragonite have been altered.

Sorby seeks to explain the phenomenon by supposing that it depends on the fact of the particles of arragonite being in a state of unstable equilibrium. When prepared artificially, arragonite has a great tendency to pass into calcite; and, if this change took place in shells, their organic structure would be very apt to be destroyed, and the solution of the calcareous matter in so far promoted. .

It is manifest that if, by expelling their carbonic acid, when the shells are burnt to quick-lime, nearly half the weight of the original dry shells is lost, a given weight of shell-lime must contain nearly twice as much phosphoric acid and potash and magnesia as is contained in an equal weight of shells, such as those from which the quick-lime was prepared. Thus, while a ton of oyster-shells contains $1\frac{1}{4}$ lbs. of phosphoric acid and three-fourths of a pound of potash, — as will be shown directly, — a ton of oyster-shell lime might contain about $2\frac{1}{4}$ lbs. of phosphoric acid and $1\frac{1}{3}$ lbs. of potash. All this consists perfectly with the results

* "Report of the British Association for the Advancement of Science," 1862, p. 95 of the abstracts. See also Pengelly, "Quarterly Journal of Science," 1871, S. 328.

of my field experiments, published in the first volume of the " Bussey Bulletin " (see, for example, pages 86 and 136). Both oyster-shells in fine powder and oyster-shell lime did better fertilizing service in those experiments than the other kinds of lime that were employed in comparison with them ; but the oyster-shell lime was distinctly better than the unburnt shells, although the latter were extremely finely powdered.

The following table, which gives the number of pounds of phosphoric acid, potash, nitrogen, and magnesia contained in a ton (2,000 lbs.) of the several kinds of shells examined in this laboratory, will perhaps present the economic side of the question a little more clearly than the previous table of percentage composition : —

A Ton (2000 lbs.) of the Dry Shells of the —	Contains (in round numbers) pounds of—			
	Phosphoric Acid P$_2$O$_5$.	Potash K$_2$O.	Nitrogen N.	Magnesia MgO.
Lobster	62½	5¼	79½	31¼
Common Crab . . .	71	4½	39	—
King Crab	5¼	1¼	251	—
Oyster	1¼	¾	1¾	5¼
Clam	¾	¼	1	⅜
Quahaug	⅛	¾	½	—
Hen Clam	⅓	½	¾	—
Smaller Mussel . .	½	⅜	5⅔	—
Horse Mussel . . .	⅜	⅓	¼	—
Scallop	1¼	⅜	0	—
Sea Snail	⅓	$\frac{9}{10}$	0	—

Methods of Analysis. For the estimation of *phosphoric acid*, a quantity of the dry powder was dissolved in strong nitric acid, and the solution was evaporated to dryness, and heated to 110°, to render silica insoluble. In the filtrate from silica, the phosphoric acid was thrown down with molybdate of ammonia, and estimated in the usual way. See page 24.

For the estimation of *potash*, a quantity of the shell was ignited in a crucible, or roasted in a muffle to destroy organic matter, chloride of ammonium was mixed intimately with the calcined powder, in the proportion of one part of the chloride to about eight parts of the powder; and the process was proceeded with precisely as in Professor Lawrence Smith's method of estimating potash in silicates. As much as 20 grms. of the shell were operated upon, *i.e.*, ignited with the chloride, in most instances.

Nitrogen was estimated by the soda-lime process, care being taken to powder the materials very finely, and to use large quantities of material for those determinations, where the proportion of nitrogen in the shells was small.

To estimate *magnesia* in the sea-shells proper, ten grammes or more of the powdered shell that had been calcined to destroy organic matters were dissolved in chlorhydric acid, and a mixture of chloride of ammonium, carbonate of ammonia, and caustic ammonia, was added directly to the solution, in order to precipitate the lime, as well as any iron or alumina that might be present, and the trace of phosphoric acid also.   The filtrate from the lime precipitate was evaporated to dryness, to expel ammonium salts; and the residue, after having been taken up with acid, was treated with oxalate of ammonia to remove the last traces of lime.   In the filtrate from oxalate of lime, magnesia was precipitated as phosphate of magnesia and ammonia, in the usual way.   In the case of the lobster-shell, it was found necessary to remove phosphoric acid in the first place by precipitation as phosphate of iron, before proceeding to remove the lime, as above.

For the sake of completeness, I have compiled the following table of analyses of shells, published hitherto, that seem to be trustworthy. Several well-known analyses have been purposely omitted from the table either wholly or in part since they are manifestly incorrect, particularly in respect to the item phosphoric acid.   An analysis of mussel-shells by Payen, for example, that has been often cited,* has been excluded on this account; and so has Reichardt's estimation of phosphoric acid (analysis No. XI. of the table).   The old analysis of oyster-shell by Bucholz and Brandes (Watts's " Dictionary of Chemistry," 4. 322), which is still often cited, must be regarded as incorrect, in so far as phosphoric acid is concerned, since the percentage of this constituent is given as 0.55, *i.e.*, the equivalent of 1.2% of phosphate of lime; 98% of carbonate of lime was reported by these chemists, and 0.5% of albuminous substance.

It will be noticed that the Roman numerals in the first column of the table correspond with those of the paragraphs below it in which the names of the materials and the authorities are given.

* Compare Wilda's " Centralblatt," 1858, 6. (II.) 88.

	Organic Matter.	Silica and Sand.	Phosphoric Acid.	Nitrogen.	Carbonate of Lime.
I.	44.76	——	2.281	——	49.26
II.	44.30	——	3.069	——	49.00
III.	36.50	——	3.069 (sic)	——	56.80
III. A.	39.49	——	4.97	——	77.14
III. B.	34.99	——	4.62	——	76.66
III. C.	33.33	——	4.50	——	——
III. D.	38.18	——	4.58	——	77.52
III. E.	35.59	——	5.31	——	76.52
III. F.	35.90	——	9.16	——	——
III. G.	38.40	——	9.21	——	60.05
III. H.	91.46	——	trace	——	——
IV.	17.18	——	6 440	——	68.36
V.	12.75	——	8.589	——	68.25
VI.	28.60	——	3.390	——	62.80
VII.	3.09	——	0.311	some	96 13
VIII.	{3.17 / 3.48}	1.495	0.106	0.15o	93.97 *
IX. A.	{0.80 / 2.20}	—— / ——	—— / ——	—— / ——	98.20 / 94.70 }
IX. B.	6.27	——	——	——	89.09
IX. C.	4.70	——	——	——	88.59
X.	5.02	0.203	0.048	——	93.88 *
XI.	3.21	0.205	?	——	93.69
XII.	1.00	——	0.229	——	98.50
XIII. A.	0.95	——	1.15	about 0.389	96.07
XIII. B.	6.42	0.35	2.53	——	86.75
XIV.	1.50	——	——	——	98.50
XV.	3.88	——	0.413	——	95.22
XVI.	{2.01 / 2.04}	9.164	0.001	0.070	97.37 *
XVII.	4.44	9.530	0.055	——	92.93
XVIII.	1.49	——	0.250	——	97.96
XIX.	1.00	——	0.280	——	98.39
XX.	1.61	1.580	0.140	——	95.81 *
XXI.	——	——	——	0.052	——

I. Lobster-shell. Chevreul, cited in Schweigger's " Journal für Chemie und Physik," 1821, **32.** 495.

II. Lobster-shell (*langouste*). Fremy, " Annales de Chimie et de Physique," 1855, **43.** 94. Fremy states.that the calcareous matter is deposited very irregularly in the shells of crustaceans. He has found the proportion of inorganic matter vary from 37 to 47 % in different parts of the shell of one and the same individual.

See, further, Schmidt's analysis of the ash of lobster-shell on page 179. For an old analysis of lobster-shell by Merat-Guillot, see " Annales de Chimie," **34.** 71.

III. Shell of the crawfish (*écrevisse*). Fremy, " Annales de Chimie et de Physique," 1855, **43.** 94.

III. A, B, C, D. Full-grown shells of crawfish (*Astacus fluviatilis*), respectively 8, 7, 6, and 4.4 cm. long. Weiske, " Die landwirthschaftliche Versuchs-Stationen," 1877, **20.** 45.

III. E. Shells of crawfish, 5.5 c.m. long, that were not yet completely hardened. Weiske, as in III. A.

* How's figures refer to " lime and carbonic acid."

III. F. G. Old shells of crawfish, respectively 6.3 and 5.4 cm. long, that were about to be shed, a new thin cell having already formed beneath them. Weiske, as in III. A.

III. H. New shell of crawfish, that was forming under the old shell of III. G. Weiske, as in III. A.

All these specimens — III. A. to H. — contained traces of magnesia.

IV. Claws of the crawfish (*Krebsscheeren*). Gœbel and Pagurus, Schweigger's "Journal für Chemie und Physik," 1823, **39.** 440.

V. The glossy brown points on crawfish claws and the so-called crab's teeth (*Krebszähne*). Gœbel and Pagurus, as above.

See, further, Schmidt's analysis of the ash of the shell of the crawfish, page 179.

VI. Shell of the crab (? *Cancer pagurus*), called *Taschenkrebs* in German. Chevreul, cited in Schweigger's Journal, as above, under No. I.

VII. Shells of *Lepas lœvis*. C. Schmidt, "Annalen der Chemie und Pharmacie," 1845, **54.** 817.

VIII. Shells of the European oyster (*ostrea edulis*). How, "American Journal of Science," 1866, **41.** 379. Beside the items in the table, he found 0.800 and 0.809 % sulphuric acid, and 0.039 % ferric oxide.

IX. Different parts of the oyster-shell, as follows : —

A. The inner lustrous pearly layer of the shell.

B. Hard brown scales from borders of the laminæ upon the outermost part of oyster-shells.

C. Dull, chalky, friable matter from spaces between the laminæ of the oyster-shell. Schlossberger, "Annalen der Chemie und Pharmacie," 1856, **98.** 101.

X. Shell of the European mussel (*Mytilus edulis*). How, as cited under No. VIII. He found, also, 0.35 % sulphuric acid, and 0.036 % ferric oxide.

XI. Mussel-shells. Reichardt, Wilda's "Centrallblatt," 1859, **7.** (II.) p. 421. These shells gave off 0 58 % of water on being heated.

XII. Shell of the garden or vineyard snail (*Helix pomatia*). Gobley, "Journal de Pharmacie et de Chimie," 1858, **33.** 161. He found traces of magnesia and ferric oxide also.

XIII. A. Snail-shells, as in XII. B. Wicke, "Annalen der Chemie und Pharmacie," 1863, **125.** 79. He found 0.467 % of magnesia also.

XIII. B. Operculum of the garden snail. B. Wicke, as in XIII. A. Beside the items in the table, he found 0.457 % of magnesia, and 0.085 % ferric oxide For W. Wicke's analysis and remarks upon the operculum of the snail, see the note on page 192.

XIV. Snail-shells, as in XII. Joy, "Annalen der Chemie und Pharmacie," 1852, **82.** 867.

XV. Shells of *Helix nemoralis*, dried at 120° C. Schmidt, "Annalen der Chemie und Pharmacie," 1845, **54.** 813. He noted a trace of magnesia also.

XVI. Shell of the European periwinkle (*Littorina littorea*). How, as cited under No. VIII. He found 0.282 and 0.288 % of sulphuric acid also.

XVII. Shells of the common cockle of Europe (*Cardium edule*), Phipson, "Report British Association," 1859, p. 77. He found also a trace of potash, 0.18 % of magnesia, 0.2 % of sulphuric acid, 0.41 % of ferric oxide, and 1.10 % of water.

XVIII. Shells of *Anodonta*, dried at 120° C. Schmidt, "Annalen der Chemie und Pharmacie," 1845, **54.** 813.

XIX. Shells of *Terebratula*. Sharples, " American Journal of Science," 1871, **101.** 169.

XX. A Silurian fossil-shell (*Leptæna depressa*). How, as cited under No. VIII. He found also 0.55 % sulphuric acid, and 0.26 % ferric oxide.

XXI. Dried sea-shells from the coast at Dunkirk. Boussingault and Payen, " Annales de Chimie et de Physique," 1842, **6.** 463.

Note to No. XIII. B. of the foregoing Table and List of Authorities. The operculum of the garden snail serves only a temporary purpose. In late autumn, the shell of the snail is closed by means of it, and it remains in place during the winter while the snail is buried in the earth. But when the animal wakes again in the spring, the operculum is cast off. W. Wicke found, in 1853 ("Annalen der Chemie und Pharmacie," **87.** 224), that this operculum differed decidedly in composition from the shell proper. According to him, both the inner and outer surfaces of the operculum are covered with small warts, supposed to consist chiefly of phosphate of lime, which separate in the form of little corns when the substance is treated with tolerably concentrated acetic acid, and finally dissolve in the acid without effervescence after the whole of the carbonate of-lime has gone into solution. After having treated the operculum with warm dilute potash-lye, to remove organic matter, W. Wicke found in it 94.24 % of carbonate of lime, and 5.73 % of bone phosphate of lime ; *i.e.*, 2.63 % of phosphoric acid, beside traces of oxide of iron and magnesia.

In the operculum of a species of *Trochus* from the Mediterranean Sea or the Indian Ocean, W. Wicke found 98.72 % of carbonate of lime, and 1.28 % of organic matter, and traces of phosphate of magnesia. It will be observed that in this case, where the operculum is permanent, and is used during the entire life of the animal, it appears not to differ materially in composition from the shell proper.

In the following recent shells, Schlossberger (" Annalen der Chemie und Pharmacie," 1856, **98.** 102) found the stated amounts of carbonic acid, from which data he has calculated the corresponding amounts of carbonate of lime. The shells appear to have been thoroughly dried before being subjected to analysis : —

	CO_2.	CaO,CO_2.		CO_2.	CaO,CO_2.
Venus decussata . .	41.14 %	93.51 %	Cypræa moneta . . .	40.85	92.85
Valve of Turbo rug. .	42.43	96.55	Oliva ?	41.00	93.20
Mytilus edulis (young examples)	36.12	82.12	Turbo neritoides . .	40.89	92.48
Bulimus radiatus . . .	41.10	93.41	Turritella fuscata . .	39.02	88.76
Voluta rustica	40.45	92.10	Pupa (W. Indies) . .	41.10	93.48
Cypræa erosa	41.45	94.21	Anodonta anatina . .	39.15	88.99
Cypræa chinensis . . .	41.86	95.16	Helix nemoralis . . .	36.34	82.62

In seven different species of corals from the American coast, Sharples * found from 0.12 to 0.39 % of phosphoric acid, from 1.64 to 3.79 % of water plus organic matter, and from 95.37 to 98.07 % of carbonate of lime. For other estimations of the amount of phosphoric acid and the other constituents in coral, see Silliman's paper in " American Journal of Science " (2), **1.** 189, and Damour, Liebig and Kopp's " Jahresbericht der Chemie," 1850, **3.** 812, and 1851, **4.** 865.

* " American Journal of Science," 1871, **101.** 168.

In the axes of various sea-pens (*Pennatula*), Fremy [*] found from 31.2 to 48% of ashes. A more complete analysis of the axes of two kinds of *Pennatula* gave the following results: —

	I.	II.
Organic matter, insoluble in acids	16.40	11.10
,, ,, soluble ,,	15.64	19.33
Carbonate of lime	44.26	53.57
Phosphate ,,	23.70	16.00
[Or phosphoric acid	10.86	7.33]

An important exception to the general rule, that sea-shells consist chiefly of carbonate of lime, was detected by Logan and Hunt,[†] by whom, and by Cloez [‡] also, several years later, it has been shown that some kinds of shells, such as were specially abundant in the waters of the earliest geologic periods, contain a very large amount of phosphate of lime. Logan and Hunt found not only that fossil-shells of the *Lingulæ*, which occur in the lower Silurian rocks, consist chiefly of phosphate of lime, but that the shells of existing species of *Lingula* are equally phosphatic. They examined particularly *Lingula prima* and *L. antiqua* from the Potsdam sandstone, *L. parallela* from the calciferous, and a species somewhat resembling *L. quadrata* from the Trenton limestone; all of which shells, it is to be noted, dissolved readily in dilute chlorhydric acid, with slight effervescence. The shell of a recent species (*Lingula ovalis*) from the Sandwich Islands was found to have the same composition as the fossil-shells; the thick, green epidermis, which swelled up like horn when heated, gave a bulky, white ash of phosphate of lime. On being calcined over a spirit-lamp, the shell, with its epidermis, lost 38.6% of its weight; and the calcined shell contained 85.79% of phosphate of lime (equivalent to 39.30% of phosphoric acid), 11.75% of carbonate of lime, and 2.8% of magnesia. "The proportion of phosphate of lime is that contained in human bones after their organic matter has been removed."

Cloez found in shells of *Lingula anatina*, dried at 100°, 45.2% of organic matter, 42.29% phosphate of lime, 3.85% phosphate of magnesia, 6.68% carbonate of lime, and 1.98% phosphate of iron, and traces of silica. The organic matter contained nitrogen and sulphur.

Logan and Hunt found, furthermore, that an undescribed fossil species of *Orbicula* from the Trenton limestone, and another large undescribed species of *Orbicula* from the upper Silurian as well as the shell of a recent species (*O. lamellosa*) from Callao, consisted like the *Lingula* shell, chiefly of phosphate of lime. The shell of *Conularia trentonsis* also proved, on examination, to be largely composed of phosphate of lime.

For the sake of comparison, Logan and Hunt examined a number of other fossil shells, viz., *Atrypa extans*, *Leptæna alternata*, and *Orthis pec-*

[*] " Annales de Chimie et de Physique," 1855, **43.** 98.
[†] " American Journal of Science," 1854, **17.** 285.
[‡] Kopp and Will's " Jahresbericht der Chemie," 1859, **12.** 642.

tenella, from the Trenton limestone; *O. enatica*, from the Hudson River group, and *Chonetes lata* (?), from the upper Silurian; besides *Isotelus gigas*, and a species of *Cythere*, from the Trenton; all of which were found to consist of carbonate of lime, with only such traces of phosphate as are generally found in calcareous shells.

I am indebted to my assistant, Mr. J. Andrew Henshaw, for aid in this research.

No. 18. — *On the Prominence of Carbonate of Lime as a Constituent of Solutions obtained by Percolating Dry Cultivable Soils with Water.*   By F. H. STORER, Professor of Agricultural Chemistry.

ON the occasion of percolating a considerable quantity of an ordinary loam with distilled water, I have recently been forced to observe, more distinctly, it would seem, than any one had ever observed before, that carbonate of lime is dissolved in abundance from most cultivable loams, when they are treated with cold water after they have long been dry.   Even the purest water, which is of itself completely free from carbonic acid, produces this effect, and will be found to hold dissolved a noteworthy amount of carbonate of lime after it has been allowed to trickle through a quantity of the dry loam.

The solution of the lime-carbonate is manifestly due, at least for the most part, to the presence of carbonic acid, which the water takes up from the pores of the soil; and the formation of the solution of supercarbonate of lime is so general with different specimens of loam, and so well marked, that it is impossible to escape the conviction that it must play a highly important part as an active chemical agent in the economy of nature.   It is plain that the solution in question must often exert no inconsiderable influence upon the formation of soils and the growth of crops, as well as upon the maintenance of the fertility of the land, even in countries that are wholly devoid of limestone, in the ordinary acceptation of the idea.   The special abundance of the soluble lime-carbonate in earth that has long been dry goes to show, moreover, that the occasional absence of water from soils may, perhaps, be advantageous.   In other words, it is not improbable that droughts are sometimes useful, by promoting the disintegration of the soil in a way that has hitherto been unsuspected.

The fact of finding carbonate of lime in solution in water in which loam has been soaked is not new.   De Saussure,* for example, found, long ago, in his experiments on the extractive matter of soils, that dry loams of various kinds, which he moistened with water free from carbonic acid, and left to stand for several days, and then subjected to

* "Récherches Chimiques sur la Végétation," Paris, 1804, pp. 168, 169.

pressure, gave liquids in which precipitates of carbonate of lime were formed, on the addition of lime water. He remarks, incidentally, that these precipitates were not much larger than those obtained from the water of ordinary springs, and that 100 cubic inches of the liquid expressed from a loam gave off only about two inches of carbonic acid, on being boiled. Verdeil & Risler,* also, on the occasion of their experiments upon the soluble matters in soils, remark that carbonate of lime is found in the extract or aqueous solution obtained from loams, as well as in the ashes which are left on burning the dry residues obtained by the evaporation of such solutions. Many other analyses † of waters that have filtered through earth point more or less emphatically toward the conclusion that carbonate of lime is, at the least, occasionally present in the waters of surface soils. But, in so far as I am aware, it has not been recognized hitherto that long-continued dryness of the surface soil (in the case, at least, of soils which are not naturally calcareous) is an important condition for the effective solution of the lime-carbonate on the addition of water.

To illustrate the fact of the solubility of the lime-carbonate, a quantity of loam no larger than will fill a tube 40 cm. high and 2½ cm. in diameter is amply sufficient; and I have no reason to doubt that a much smaller quantity of earth than this would serve the same purpose. On pouring water upon the top of the column of dry earth until the latter has become supersaturated so that drops begin to fall from the bottom of the tube, and then testing the filtrate, either with lime water, ammonia water, or caustic soda,‡ a flocculent precipitate of carbonate of lime will be produced. It may readily be shown, moreover, in other ways, that the filtrate from the earth contains carbonic acid. Not only do the precipitates just mentioned effervesce freely on being separated from the liquid and treated with an acid, but on taking some of the original filtrate, to which no reagent has been added, placing

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* "Journal für praktische Chemie," 1852, 57. 115.

† Compare the authorities cited by Professor Johnson in his "How Crops Feed," pp. 310–314.

‡ It may here be said that the utmost pains were taken to use perfectly pure reagents in this research. The ammonia water was carefully freed from carbonic acid by redistillation from milk of lime, and the soda was prepared immediately before using it by exposing metallic sodium to the air. The lime water was boiled just before use, and drops of the percolate were allowed to fall into the hot liquid.

it in a little flask provided with an abduction tube, the outer limb of which dips in lime water, acidulating the contents of the flask, and then heating them, carbonic acid will distil over into the lime water, and there yield an abundant precipitate. Even when the extract of earth is simply boiled in the flask without acidification, a quantity of carbonic acid will go forward and react upon the lime water. On the other hand, the presence of lime in the earth extract — and in the precipitate also that is produced by adding ammonia water or the like to the extract — is readily shown by testing with ammonium oxalate.

It is not in the first drops, merely, of the filtrate that carbonate of lime may be found. On the contrary, the subsequent fractions of the percolate contain an abundance of it. Indeed, the process of washing out the carbonate is usually extremely tedious. It would hardly be an exaggeration to assert of some of the air-dried loams examined in this laboratory that so long as a supply of water is maintained at the top of the column of earth a solution of carbonate of lime will drop from the bottom of the column ; though, naturally enough, some of the earlier fractions of the percolate contain a larger proportion of the carbonate than those which come afterward. These remarks are, of course, meant to apply particularly to ordinary loams or cultivable soils. When the soil experimented upon is of exceptional or extreme character, such as peat or sand, for example, the small amount of lime contained in it will be quickly washed out, and it is only in the first fractions of the percolate that the reactions of carbonate of lime can be obtained. With pure sand the reaction cannot be got at all. The following description of the behavior of loams that had been kept for several years in a dry store-room at the Bussey Institution, may serve to illustrate the foregoing statement. It may here be said, that, in all the experiments recorded in this article, the earths were sifted through a sieve whose meshes were 2 to 3 mm. in diameter before being placed in the percolators.

I. *Dry loam from the Plain-field of the Bussey Institution.* A percolator 7 cm. wide and 46 cm. high, having an effective capacity of about 1,800 cc., was charged with the earth and percolated methodically with pure water, 850 cc. of which were absorbed before any drops of percolate appeared. Portions of each successive 50 cc. of the percolate were tested with ammonia water, with ammonium oxalate, with lime water added directly, and by boiling in a flask and conducting the steam into lime water, and reactions were obtained in every instance. The precipitate

produced by ammonia seemed to diminish gradually in quantity up to the sixth fraction, but became tolerably constant when 300 cc. of percolate had passed through the earth, and persisted for a long time afterward. Up to 300 cc., the fractions were tested with lime water directly, both hot and cold, and they always gave reactions. So, too, on boiling the fractions of percolate and causing the steam to pass into lime water, reactions were always obtained, even when no acid had been added to the liquid. When acid was used, a still stronger reaction occurred.   Several fractions of the percolate were tested in this way at irregular intervals between 300 cc. and 1,000 cc., and the reaction of carbonic acid was obtained in every instance.

In order to ascertain whether any of the carbonic acid could be removed from the dry earth by displacing it by means of another gas, a small column of the earth was arranged as if for percolation, and four litres of hydrogen gas that had been washed with caustic soda were passed through the earth.   The gas being received in a small volume of lime water gave a very slight reaction for carbonic acid.   The earth was then percolated with pure water in presence of the hydrogen, and the percolate tested with ammonia.   A slight precipitate of carbonate of lime was obtained. The experiment was repeated upon a larger scale, eight or ten litres of pure hydrogen being passed through 1,000 cc. of the earth and received in 20 cc. of lime water.   No reaction for carbonic acid was perceived until the lime water was boiled; but then it was well marked.   Two more litres of hydrogen being then passed through the earth, no reaction for carbonic acid could be detected on receiving the gas in hot lime water. The earth was finally percolated with pure water in presence of hydrogen, and the filtrate tested with ammonia.   A very decided precipitate of carbonate of lime was obtained.

The proportion of carbonic acid contained in successive fractions of the percolate obtained when the original dry earth was treated with water was carefully determined in several instances, with the following results: Measured quantities of the percolates were boiled with acid in an appropriate flask, and the dry carbonic acid was collected in a soda-lime tube and weighed as such.   800 grms. of the earth were percolated with pure water, and there was found in the first 500 cc. fraction of percolate 0.0065 grm. of CO_2; in the next 250 cc., 0.0075 grm. CO_2; in the next, 0.013; in the next 0.014; and in the next 0.0095 grm.   The accuracy of the process was tested as follows :   Between the third and the fourth, and the fourth and the fifth, of these trials, the soda-lime tube was reattached to the apparatus after weighing, and the contents of the flask were treated as if a new fraction of percolate had been added; but no increase of weight could be detected in the soda-lime tube in either instance.   In two other trials, each with 800 grms. of the dry earth, the first 250 cc. of percolate gave 0.002 grm. of carbonic acid, in each instance.   A single attempt was made to estimate the amount of lime in these percolates by direct titration with a highly dilute standard acid;

but no satisfactory results were obtained, on account of the extreme dilution of the lime solution, and I have not yet found time to return to the study of this question.

It is plain, from the foregoing statements, that the absolute amount of carbonate of lime and of carbonic acid contained in the percolates from dry loams are extremely small; but it is none the less true that super-carbonate of lime is a very prominent constituent of these percolates, as it is the purpose of this paper to insist. It may here be said that the amount of this substance found in the percolates from the dry loams examined in this laboratory is very much larger than that contained in the waters of several wells in the immediate vicinity of the Bussey Institution which have been tested at sundry times.

II. *Dry loam from the garden of Mr. R. Beatley, Chelsea, Mass.* 1000 grms. of the earth were placed in a smaller percolator than the foregoing, and treated with pure water. Fractions of the percolate of 50 cc. each were tested with ammonia water as before. Up to 400 cc., the precipitate was flocculent, and settled readily; afterwards, it was milky, and settled with difficulty. The percolation was continued until 1,000 cc. of liquid had passed through the earth, and the reaction with ammonia was very nearly or quite as decided in the last fraction as it had been at the 400th cc. Between the 400th and the 1,000th cc., the reaction with ammonia was still sufficient to give a very decided milkiness to the liquid; enough, for example, to render opaque the contents of a test tube 20 mm. in diameter. It would evidently have been an exceedingly wearisome matter to wash out the whole of the lime-carbonate from this earth by means of water.

III. *Dry loam from an old pasture on the farm of Henry Saltonstall, Esq., Lynnfield, Mass.* 1,000 grms. of the earth were percolated and tested, as in No. II. A flocculent precipitate was obtained in each fraction, on adding ammonia water, up to 550 cc., though the precipitate was faint in the last fractions. A very slight, hardly perceptible, cloudiness was obtained in the next fraction, but none afterward. On leaving the contents of the percolator to stand over night, and then pouring fresh water upon them, the first portions of the filtrate again gave a slight milkiness on being tested with ammonia. It was noteworthy, in this instance, that reactions for carbonic acid, as obtained by distilling the vapor of the acidified percolate into lime water, were got long after the fractions had ceased to react with ammonia water. The percolate gave a strong reaction for lime, when tested with ammonium oxalate, in one of the early fractions.

IV. *Dry peat from the Bussey Farm.* 1,000 cc. were percolated with pure water, and the filtrate tested as before. 450 cc. of the water were held by the peat before drops of percolate began to fall. Slight precipitates were obtained with ammonia water and with lime water.

V. *Dry earth from an earthen flower-pot, that had been standing for some months out of use in a dwelling-house at Rochester, Mass., gave a percolate*

with pure water, that reacted strongly, both with ammonia, and with ammonium oxalate. I am indebted to my assistant, Mr. D. S. Lewis, for this specimen, as well as for the capital idea that dry loams fit to exhibit the reaction insisted upon in this article may be found in the cellars and attics of most dwelling-houses, stored in old flower-pots.

VI. *Yellow loamy subsoil from the Plain-field.* This specimen had been kept in barrels in a dry cellar for several years. On being percolated in a cylinder of 1,000 cc. capacity, the filtrate from it gave precipitates with ammonia water only up to the 100th cc., and the volume of each precipitate was much less than that of the corresponding precipitate obtained in the extract from the surface soil. A very slight reaction for lime was obtained with oxalate of ammonia; no more, indeed, than is given by most of the well waters of this vicinity. After percolation, this specimen of soil was spread upon a plate, and exposed during four days to pure dry air in a glass house that contained no plants, and again percolated; but no reaction could now be obtained on adding ammonia to the percolate.

As would naturally be supposed, the precipitate produced by ammonia water varied considerably in appearance and composition, accordingly as it was obtained from the percolate of one or another kind of loam. In the case of the ashes and the calcined earths, to be mentioned directly, and in some of the loams proper, the ammonia precipitate was quite colorless, while in some other cases it had a slight yellow tint from the presence of organic matter. Indeed, when the precipitate was first met with in one of the latter instances, it was not suspected, for the moment, that it was really carbonate of lime. As obtained from the percolate from Mr. Beatley's garden earth, there was found in 0.132 grm. of the dry ammonia precipitate derived from the first half litre of percolate from eight to ten litres of the dry earth, as much carbonic acid as would correspond with 0.0966 grm. of carbonate of lime, and as much lime as would amount to 0.0845 grm. of carbonate of lime. In this case, therefore, the ammonia precipitate was manifestly almost pure carbonate of lime. But as obtained from a similar percolate from Plain-field earth the precipitated carbonate was much less pure, — 0.03 grm. of dry ammonia precipitate from the first half litre of percolate from eight to ten litres of Plain-field earth gave as much carbonic acid as would amount to 0.0091 grm. carbonate of lime, and as much lime as would amount to 0.0086 grm. carbonate of lime.

In these experiments, the lime was thrown down as oxalate and weighed as quick-lime, and the carbonic acid was set free with an acid, collected in soda-lime tubes, and weighed as such. Only an insignificant trace of silica was contained in these precipitates in either case.

It seemed to be evident that the lime-carbonate is held dissolved by a slight excess of carbonic acid, and that when the latter is neutralized by ammonia, the precipitate, in falling, drags down organic matters. It is possible, of course, that the organic matters which were contained in the percolates from some of the loams may have helped somewhat to dissolve

the carbonate of lime. Indeed, F. Schulze * has attributed to this cause the presence of dissolved carbonate of. lime in loam waters such as were the subject of my experiments. He says, "The soluble humus-like constituents of the soil seem to increase the solubility of carbonate of lime, since the first aqueous extract obtained after the soil has been left in contact with water for a sufficient length of time contains in solution a larger quantity of carbonate of lime than corresponds with the solubility of this substance in pure water." The idea was first suggested, I believe, by Verdeil & Risler,† who dwelt upon the fact that loams contain a neutral, soluble, organic matter analogous to sugar ‡ which facilitates the solution of a variety of inorganic matters. It is not easy to prove how much solvent action may be exerted by the organic matters of loams in respect to carbonate of lime, or whether, indeed, they have any solvent action at all for this substance. For my own part, I attach little or no importance to the idea in the present connection. It is plain, at all events, that no such solvent action could possibly have occurred in the cases of the calcined loams and ashes, to be described directly, since these substances were wholly free from organic matters. It is to be remembered withal, that there are several facts which go to show that the presence of lime salts in a soil may decidedly hinder the solution of organic matters, which become soluble when the lime salt is removed. Thus, as Knop § and Hoffmann have shown, when a loam is percolated with water, the first portions of the filtrate are commonly colorless; but after a while the succeeding portions of the filtrate are seen to be colored, — at first yellowish, and sometimes even brown. But the appearance of the coloration is coincident, as Knop urges, with the removal of a quantity of lime salts that were originally contained in the earth.

It may be said of my own experiments, that the first portions of the percolates from loams were always less deeply colored than the succeeding portions. To test the influence of an excess of lime, a quantity of dry earth from the Plain-field was mixed with whiting; enough carbonic-acid water to moisten the earth was added; the mixture was left to soak for some days in a closed flask, then transferred to a percolator, and the color of the liquor that drained from it was observed. The first 50 cc. fraction of percolate, though not colorless, seemed to be less deeply colored than usual; but the color of the subsequent fractions was similar to that of the percolates obtained from the earth alone, and on continuing the percolation with pure water, and with carbonic-acid water, the usual colorations were obtained.

Special trials were made, furthermore, in the case of the earth from the Plain-field, in order to determine whether the percolate therefrom con-

* In his "Lehrbuch der Chemie für Landwirthe," Leipzig, 1866, **1.** 676.

† "Journal für praktische Chemie," 1852, **57.** pp. 115, 117.

‡ Compare De Saussure, "Récherches sur la Végétation," p. 174.

§ In his "Lehrbuch der Agricultur Chemie," Leipzig, 1868, **1.** pp. 304, **458,** 516.

tained saline matters that could account for the solution of the lime-
carbonate; but no indication of sulphates could be detected, and the
reaction for chlorides was extremely faint.   At no time was the reaction .
so strong as that shown by a solution of chloride of ammonium containing
0.00002 grm. to the cc.; it became less and less as the percolation pro-
ceeded, and practically ceased when 300 cc. of percolate had passed
through the earth.

The effect of adding more carbonate of lime to the soils than they con-
tained naturally was tested by mixing some of this substance, in the form
of whiting, both with Plain-field earth and with sand, and percolating
the mixtures.   As a preliminary to these trials, two samples of whiting
and one of gypsum were kept in contact with pure water for several days,
with frequent shaking, then filtered, and the filtrates tested with ammonia
water.   The liquid from one sample of the whiting gave a perceptible
though slight precipitate with ammonia, while that from the other gave
scarcely any precipitate.   Hence, the second sample was used for the
experiments that follow.   The gypsum solution gave an extremely slight
precipitate with ammonia water and with lime water.

A quantity of Plain-field earth was mixed intimately with 1% of
whiting; the mixture was percolated with pure water, and the perco-
late was tested with ammonia, in comparison with a percolate obtained
from the simple earth.   The first portions of liquor from the whiting
mixture gave much stronger reactions with ammonia than those from the
earth alone; but the reaction gradually diminished in strength for a time,
and finally became constant.   When 1500 cc. of percolate had passed
through the earth, carbonic-acid water began to be poured upon the top of
the column, in place of the pure water previously used, and it was noticed
that 300 cc. of liquor came through before the percolate began to react
any stronger with ammonia or with lime water than it had reacted before.

On percolating with pure water a mixture of Plain-field earth and
1% of gypsum, the ammonia reactions obtained were similar to those
with the earth alone.

Berkshire sand, mixed with 1% of whiting and percolated with pure
water, gave no perceptible reaction with ammonia.

A series of experiments was next made with earths that had been more
or less strongly calcined.

VII. *Ashes of anthracite which had been kept five years in barrels in a dry
store-room.*   A sample leached with pure water in a large percolator
yielded a filtrate that gave abundant precipitates of carbonate of lime on
the addition of ammonia water; and so did another sample tested in a
small percolator.   But on igniting some of the dry ashes strongly in an
iron tube for half an hour to expel carbonic acid, and testing this ignited
portion in the small percolator, the first 25 cc. of filtrate gave so slight
a reaction with ammonia water that the precipitate was barely perceptible.

VIII. *Calcined loam from the garden of Mr. Beatley, as above,* No. II.

The first trials were made with some of the earth that had been slowly calcined, with frequent stirring, in a large iron muffle, at the lowest possible temperature, until the last traces of organic matter were destroyed, and had then been left to stand for four months in a loosely covered jar. On percolating a small quantity of this product, and adding ammonia water to the percolate, an immediate and abundant precipitate of carbonate of lime was obtained, as well as a strong reaction for lime on the addition of ammonium oxalate. On reheating some of this earth in an iron tube, and then percolating, only a slight ammonia precipitate was obtained in one instance, while, in another instance, there was a tolerably strong precipitate on adding ammonia. In order to determine how firmly the carbonic acid was held by the earth, a small iron tube was charged with some of that which had stood for four months after calcination, and four litres of hydrogen gas that had been well washed in caustic soda were passed through the earth and into lime water; but no reaction for carbonic acid was obtained. In order to see what influence, if any, the addition of organic matter to the calcined loam might exert, two small glass percolators of equal size were charged; one with a $40 \times 2\frac{1}{2}$ cm. column of the old calcined earth, and the other with the same volume of this earth with about one-tenth the volume of finely powdered straw. Both columns were percolated with pure water, and the percolates were tested with ammonia water. But no difference could be detected in the amounts of the precipitates obtained, and the precipitation ceased in both cases when 100 cc. of percolate had been collected.

For a second set of experiments, a new portion of the Beatley loam was calcined in porcelain dishes in a small iron muffle, with frequent stirring, at a somewhat higher temperature than the previous sample had been calcined, and the product was tested as follows : Three small equal cylinders were charged (1) with the old calcined loam that had stood in the air during four months ; (2) with the loam that had been freshly calcined; and (3) with some of No. 2 that had been again heated to redness in an iron tube, and cooled in a desiccator over quick lime. The first 50 cc. of percolate from each tube being taken, and equal portions of each sample tested with ammonia water, a precipitate was obtained in each case; but, while there was no appreciable difference in the volume of the precipitates from Nos. 2 and 3, the precipitate from No. 1 was at least twice as large as the others.

IX. *Calcined loam from Mr. Saltonstall's pasture, as in* No. III. The experiments on this loam were made several months later than those upon the calcined Beatley earth, and for the sake of controlling the latter. Two small glass percolators, each with an effective capacity of $40 \times 2\frac{1}{2}$ cm., were charged, one with loam from Mr. Saltonstall's pasture that had been calcined two years ago, and been left standing since then in a loosely covered jar; and the other with similar loam that had been calcined in precisely the same way immediately before the percolation. In both instances, the loam was slowly calcined at the lowest possible

temperature, and with constant stirring, directly upon the floor of a large ‚iron muffle; and the new sample was placed in the percolator as soon as it had become fairly cold.

Both specimens were percolated with pure water, and 25 cc. fractions of the percolates were collected for testing. It appeared in each fraction that the precipitate produced by ammonia was more voluminous in the case of the recently calcined earth than in that of the earth that had been exposed to the air for a long time after the calcining; and that, while the fourth fraction of percolate from the latter gave no appreciable precipitate with ammonia, this reagent produced a distinct precipitate in the fourth fraction from the recently calcined earth, which was as far as the experiment was carried.

Contrary to what might, perhaps, have been inferred from the results previously obtained with the Beatley earth, it seems plain, from the ·behavior of the calcined Saltonstall earth, that the excess of carbonic acid found in the percolates could not have been simply absorbed by the earth from the air after the calcination. On the contrary, the inference to be drawn from these experiments is, that a part of the carbonic acid resulting from the combustion of the organic matter of the original loam is retained with a good deal of force by the calcined product. It is here a case of "occlusion," pure and simple. The following experiments were made to test this point: A quantity of the earth that had stood two years after calcination was placed in a wrought-iron tube, and ignited for an hour as strongly as possible in a combustion furnace, while a current of air free from carbonic acid was forced through the tube, and made to pass into lime water as it left the tube. This test liquor indicated that an abundance of carbonic acid was expelled from the earth. After the ignition, the earth was allowed to cool in the current of air, and it was finally percolated with pure water; but no perceptible precipitate was produced on adding ammonia to the percolate, not even in the first 25 cc. fraction.

It was noteworthy that both the mechanical and the chemical condition of the earth had been greatly altered by the ignition. The original calcined earth was of a reddish-yellow color before its ignition in the iron tube; but after the ignition the earth was gray; and, on heating this gray product with nitric acid, the original reddish coloration was restored. To see if this reduction of ferric oxide was to be attributed wholly to the iron of the tube, another portion of the original calcined earth was heated as before, for one hour, in a combustion tube of hard glass; but this portion did not become gray, and the percolate from it gave a precipitate with ammonia.

Still another portion was finally heated as strongly as possible for two hours in a glass tube, in a current of pure dry air, and it was noticed that the color of the earth became deeper in all parts of the tube, and that at length the earth became gray at the middle of the tube where the heat was greatest, as it had done in the iron tube. On treating this gray earth

with water, a percolate was obtained that gave no precipitate with ammonia, while the percolates from those portions of the earth which from their position in the tube had been less strongly heated and had not become gray gave abundant precipitates with ammonia. In this experiment in the glass tube, carbonic acid began to be given off from the earth before the tube became very hot, certainly at low redness.

The results of these experiments are manifestly akin to those obtained by Reichardt and Blumtritt; * who found, for example, that while no carbonic acid could be detected in the mixture of gases expelled by heating some substances, such as oxide of lead, gypsum, and some samples of whiting, large quantities of carbonic acid were found in the gases expelled from garden earth, from the oxides of iron and manganese, from clay and river-mud, and various other solid bodies. As much as 80% of carbonic acid was found in the gases expelled from one sample of ferric oxide, and more than 33% in those from a sample of air-dried garden earth. But while the experiments of Reichardt and Blumtritt, upon ferric oxide and the like, point merely to the power of these substances to absorb carbonic acid from the air, at the ordinary temperature, my experiments with the calcined loams enforce the lesson, that roasted earths can retain much carbonic acid that has been formed within them by the oxidation of organic matters at the temperature of calcination. The fact of this retention of carbonic acid at high temperatures, and the easy solution of super-carbonate of lime from the roasted earths on the addition of water, suggests the inquiry whether some part of the efficacy of the processes of "paring and burning," and "clay burning," which have at times been highly esteemed in agricultural practice, may not be due to the reactions of the supercarbonate. It is not impossible, even, that some samples of coal ashes may have a slight agricultural value on this account.

In respect to the loams proper that have merely been kept dry and not calcined, I am still in doubt whether the greater part of the carbonic acid found in them has been formed there through oxidation of the organic matters of the loam, or whether a good part of it may not have been absorbed from the air, as the experiments of Reichardt and Blumtritt suggest. This point is left undecided by the results of the following experiments, which show, merely, that considerable time is required in order that a dried earth shall become charged with enough

* "Journal für praktische Chemie," 1866, 98. pp. 418, 476.

carbonic acid that it may yield a solution of supercarbonate of lime when treated with water. It would seem, at all events, from these experiments, that there is no essential necessity for supposing that the carbonic acid has been derived from the oxidation of the organic portion of the loam, in the case of the earths that have long been dry.

For the present, I wish merely to insist upon the fact, that much more carbonic acid will usually be found in loams that have been kept for a long time in a thoroughly dry condition, than in fresh earth or in that which has only recently been dried. The experiments which have forced this conviction upon me are here given in detail.

Fifteen separate samples of fresh loam were dug up from the Plainfield on different days between May and October, 1877 ; and these fresh earths were percolated and tested for carbonic acid, and particularly for the precipitate of carbonate of lime that is produced by ammonia water. The different samples differed widely among themselves as to their condition of dryness, accordingly as the weather had been rainy or dry before the times of collecting them ; but the results of the tests were constant and unvarying. No appreciable precipitate was produced by ammonia in the percolates from any of the samples ; and only faint traces of carbonic acid were detected on boiling the acidulated liquids in a flask, and conducting the vapor into lime water.

In the case of several of these specimens, a portion of the earth was dried rapidly, either completely upon a water-bath, or by spreading the earth upon plates, and leaving it to become air-dried in a dry glass house in which no plants were growing. But, like the fresh earth, these recently dried earths gave no precipitate when percolated and tested with ammonia. On leaving the dried earths, however, for six or eight days, exposed to the pure dry air of the glass house, and then percolating them, precipitates were obtained on the addition of ammonia water. In one instance, a quantity of earth collected June 11 was left exposed to the air in the glass house, until June 18, when a portion of it being percolated, and tested with ammonia, gave a slight precipitate of carbonate of lime. The remainder of the dry earth was then divided into two equal portions, one of which was placed in a tightly stoppered bottle, while the other was again spread out and exposed to the air in the glass house for a month. The two portions were then percolated, and tested with ammonia under precisely similar conditions ; and it was found that the precipitates obtained from the

earth which had been exposed to the air were at least twice as bulky as those from the earth that had been bottled. Indeed, the precipitates from the bottled earth appeared to be no larger than those obtained a month earlier from the earth that had been dried a week. It was noticed, however, that the percolates from the earth that had been exposed to the air were more highly colored than those from the bottled earth.

Other samples of fresh loam, and of loam that had just been dried, taken from various localities, gave results similar to the foregoing. Some of these specimens were taken from cultivated fields, others from beneath sods both in woodland and in mowing fields. Most of them were from the Bussey Farm or its vicinity; but one was from an old pasture at Rochester, Mass. Not one of these specimens gave any reaction with ammonia, when that substance was added to the percolates from the earths that had been spread out and left for two or three days in the glass house until they were air-dried. Most of them, on the other hand, gave abundant precipitates with ammonia, when percolated and tested, after having been exposed to the air in the glass house for one month. But there were exceptions to this rule, as will appear from the following statement: —

Four specimens of earth were tested methodically, in such wise that the percolates from 1,000 grm. portions of the earths — both those recently dried, and those that had been dried a month — were contrasted, in respect to the amount of carbonic acid in each, and to the amount of solid matter left on evaporating a measured volume of the percolate. Half a litre of percolate was collected in each instance. All the percolates were tested with ammonia-water, also, to see if any precipitate would form.

Each of these loams were taken fresh from the fields, and left to dry in the air two or three days, as above stated, before the first percolation, and to dry in the air for a month before the second percolation. No. I. was loam from the Plain-field; No. II., loam from beneath the sod of a mowing field; No. III., from woodland beneath a pine tree; No. IV., subsoil that had been thrown aside by workmen in excavating a gravel pit. This earth (No. IV.) was very fine, though not clayey. It seemed to be well-nigh free from organic matter.

It was found that 500 cc. of the percolates contained the following amounts of carbonic acid and of dry extract: —

No. of the loam.	Time of drying.	Grms. CO_2.	Grms. solid residue.	Reaction with Ammonia.	The loams contained per cent of moisture.
I . .	two or three days	0.0332	0.210	0	2.63 %
	one month . . .	0.0462	0.275	Distinct	1.57
II . .	two or three days	0.0292	0.160	0	0.58
	one month . . .	0.0700	0.285	Decided	1.26
III .	two or three days	0.0325	0.150	0	2.20
	one month . . .	0.0200	0.820	0	1.10
IV .	two or three days	0.0037	0.085	0	0.95
	one month . . .	0.0050	0.700	0	0.57

The reasons of the exceptional behavior of Nos. III. and IV. deserve to be carefully studied. No. III., it will be noticed, was a woodland earth rich in humus, and No. IV. a subsoil that was supposed to be well-nigh free from organic matter. It is probable that the explanation of the apparent anomaly will be found in the formation of organic acids in the earths, as has been insisted upon by Mulder;[*] and it may well be true that the formation of such acids in times of drought is as characteristic for some kinds of soils as the formation of carbonic acid is for other kinds. It may here be reiterated, that all the normal cultivable loams thus far examined in this laboratory have shown an increase of carbonic acid on being kept, as indicated by the reactions of their percolates with ammonia water.

Several trials were made to determine how the moist and recently dried loams would behave when percolated with carbonic-acid water, instead of pure water, and it appeared, in every instance, that the earth either decomposed the carbonic-acid water to a considerable extent, or in some way retained the carbonic acid in such wise that no increase of this substance could be detected in the percolate until an appreciable volume of the liquid had passed through the earth. For example: A quantity of earth was taken from the Plain-field, June 1, at a time that was neither wet nor dry, and placed immediately in a cylinder 7 $\times$ 46 cm.; carbonic-acid water being then poured upon the top of the column of earth, 350 cc. of the liquid were absorbed by it before any drops began to fall; but no reaction for carbonic acid was obtained, by testing directly with lime water, until 300 cc. of percolate had been collected; and 100 cc. more of the liquid passed through the earth before the percolate gave a reaction for carbonic acid that was comparable with that given by the carbonic-acid water itself, which had not been in contact with the earth.

In one instance, where a similar column of fresh Plain-field earth had been percolated with pure water, of which 300 cc. were required

[*] In his "Chemie der Ackerkrume," Berlin, 1868, 1. pp. 527, 445.

to saturate the earth, the water was followed by carbonic-acid water, and no direct reaction for carbonic acid with lime water was obtained until 550 cc. of percolate had passed through the earth In another similar instance, where the earth had been dried a week, then percolated with pure water (of which 850 cc. were required to saturate it) until the percolate no longer gave a precipitate with ammonia, and then treated with carbonic-acid water, 1,000 cc. of percolate came through before carbonic acid could be detected by direct tests with lime water ; and some 200 cc. more came through before the reaction for carbonic acid was as strong as in the original carbonic-acid water. This point was finally tested with the utmost care as follows : A quantity of earth taken directly from the Plain-field was dried as rapidly as possible upon a water bath, and 1,000 grms. of the dry earth were percolated, first with pure water, and then with carbonic-acid water. 475 cc. of water were required to saturate the earth. The pure water percolate gave a slight indication of carbonic acid when boiled with lime water ; but no reaction occurred when drops of the percolate were allowed to fall into hot lime water. Carbonic-acid water was then poured upon the column of moist earth and the percolate was tested methodically, by allowing two or three drops of it to fall into 10 cc. portions of hot lime water contained in a test tube. After beginning to use the carbonic-acid water, nearly 600 cc. of percolate came through before a drop of it falling into lime water produced any perceptible cloudiness. After 600 cc. of liquid had passed, the cloudiness increased gradually, as the drops fell into lime water ; but the reaction was not as strong as that given by the original carbonic-acid water until about 700 cc. of percolate had been collected.

Another 1,000 grm. portion of the dried earth was percolated with carbonic-acid water directly, without the previous addition of any water. 475 cc. of the liquid were absorbed by the earth, and 150 cc. of percolate came through the earth before any cloudiness could be detected on dropping the percolate into hot lime water. This cloudiness became more decided in the later portions of the percolate ; but at 300 cc., when the experiment was brought to a close, it was not equal to the reaction obtained with the original carbonic-acid water.

When, instead of carbonic-acid water, dry carbonic-acid gas was passed through the earths, as contained in the cylinders, and the earths thus charged with the gas were percolated with pure water, precipitates

of carbonate of lime were, immediately obtained, on adding ammonia water or lime water to the percolates. This result was obtained with fresh earth from the Plain-field that was operated upon directly, and with similar earth that had been rapidly dried upon a water bath.

Very different results from those just now described were obtained when the earths that had been kept dry for years in a store-room were percolated with carbonic-acid water. Thus, on charging a cylinder with 1,800 cc. of the Plain-field earth that had long been dry, and percolating immediately with carbonic-acid water, 800 cc. of the liquid were absorbed by the earth, and the reactions of carbonic acid were obtained in the first 50 cc. of the percolate. As has been said already (p. 198), the reactions of carbonic acid were obtained in percolates from this earth when nothing but pure water was used. An almost precisely similar result was obtained in another trial: that is to say, 825 cc. of carbonic-acid water were absorbed by the earth, and the reactions of carbonic acid were obtained immediately when the percolate appeared. In one of these trials, the percolation with carbonic-acid water was continued until two litres of liquid had passed through the earth; but the percolate continued to react with ammonia from first to last, and the reaction for lime was obtained constantly with ammonium oxalate also.

An effort was made to determine quantitatively the amounts of carbonic acid that came through the earth in successive 50 cc. portions of the percolate, when 1,000 grms. of the dry store-room earth were percolated with carbonic-acid water. The filtrates were acidulated and boiled, and the carbonic acid was collected in a soda-lime tube, and weighed as such. 50 cc. of the original carbonic-acid water contained 0.062 grm. of carbonic acid, and there was found in the first 50 cc. fraction of the percolate 0.004 grm. of CO_2; in the second, 0.010 grm.; in the third, 0.011; in the fourth, 0.009; and in the fifth and sixth together, 0.019. 250 cc. of the percolate were then allowed to flow to waste, after which, 50 cc. of the liquid gave 0.027 grm. of CO_2.

In one experiment, where 1,800 cc. of dry earth from the store-room were percolated, first with 1,850 cc. of pure water, of which 850 cc. were required to saturate the earth, and then with carbonic-acid water, 900 cc. of liquid came through before a sufficiently decided reaction for carbonic acid to be attributed to the carbonic-acid water was obtained. On testing with ammonium oxalate, also, the reactions for lime were about as strong before the carbonic-acid water began to come through as afterward. 1,000 cc. of carbonic-acid water were passed through the earth in this

experiment, and afterwards 1,200 cc. of pure water; but the reactions for carbonic acid and for lime persisted to the end.

The interference of the loam with the action of the carbonic-acid water was still further illustrated in the following quantitative experiment, which was made in the hope of gaining some slight idea of the amount of lime that was dissolved from the loam by carbonic-acid water. 1,000 cc. of the dry store-room earth were percolated with carbonic-acid water, each 50 cc fraction of the percolate was supersaturated with dilute standard acid, and the amount of this acid neutralized by matters in the percolate was determined by titrating back with a tenth-normal solution of borax. It appeared that the following amounts of acid were neutralized by the several fractions of percolate, from the first to the fifth respectively; viz., 0.7 cc., 0.9, 1.0, 1.0, and 1.2 300 cc. of percolate were then allowed to flow to waste, and afterwards, three other fractions were tested with acid, with the following result. These new fractions were each of 100 cc.: the first neutralized 2.5 cc. of acid; the second, 2 cc., and the third, 2.5 cc. The acid employed was nitric, one-tenth normal. Each centimetre of it was equivalent to 0.0028 grm. CaO, or to 0.005 grm. CaO, CO_2.

Other experiments were made in this connection by percolating quantities of similar earth with a solution of carbonate of lime in carbonic-acid water. In one trial, where 1,000 cc. of earth were taken, and the lime solution employed was of such strength that 50 cc. of it neutralized 7 cc. of the acid, the first six fractions, each of 50 cc., neutralized the following amounts of the acid; viz., 1.2 cc. 1.3, 1.5, 1.5, 1.6, and 1.6. In another trial, where 250 cc. of the earth were taken, and 50 cc of the original lime solution neutralized 6.9 cc. of the tenth-normal acid, the first ten fractions of the percolate neutralized respectively 1.5 cc., 1.7, 2.2, 2.4, 2.5, 2.6, 3.5, 4.0, 5.0, and 7.0 cc. of the acid.

On percolating 1,800 cc. of pure dry Berkshire sand with carbonic-acid water, the very first portions of the percolate gave the reactions of carbonic acid. 500 cc. of the carbonic-acid water were gradually poured in at the top of the cylinder (of 46×7cm.), and nearly 75 cc. of liquid came through; i.e., 425 cc. were absorbed by the sand. The sand thus moistened with carbonic-acid water was then percolated with pure water, and the reactions of carbonic acid were obtained in the percolate up to 1,000 cc., when the apparatus was left to stand over night: on percolating again next morning, the first 50 cc. of liquid gave no reaction for carbonic acid.

In another experiment, dry Berkshire sand was saturated with about 400 cc. of pure water, and then percolated with carbonic-acid water. The reactions of carbonic acid were obtained when 450 cc. of percolate had been collected.

It would seem to be plain from all the experiments here cited, that when carbonic-acid water comes in contact with moist earth it is de-

composed to a certain extent; *i.e.*, the gas is removed from the first portions of the liquid, either by being absorbed from it directly by the earth, or by being made to escape from the water through the mechanical action of the earth.* In the cases where carbonic-acid water was poured upon earth that had been kept dry for a long while, the first portions of the liquid evidently acted as mere water to dissolve and push out the carbonated lime-compound that already existed in the earth, or was ready to be formed there on the arrival of the water.

Some important facts first observed by Bineau † are to be remembered in this connection. He found, for example, that the carbonic acid contained in dilute solutions of supercarbonate of lime is much less readily expelled than carbonic acid that is simply dissolved in water. In a word, he found that dilute solutions of the acid carbonate of lime are not easily decomposed, and that they retain the excess of carbonic acid, over and above that contained in the normal carbonate, much more forcibly than pure water can retain it. Very dilute solutions of the acid carbonate may even be heated to the temperature of boiling, or left to stand in the exhausted receiver of an air pump without losing the excess of carbonic acid, or depositing carbonate of lime. He found that solutions of the acid carbonate which contain $\frac{1}{10000}$ or less of normal carbonate of lime are in so far permanent that they do not give off carbonic acid at the ordinary temperature of the air. Such solutions are decomposed only by actual evaporation of their water, or by reacting chemically upon some other substance. But it is precisely these highly dilute solutions of the acid lime-carbonate that occur naturally in the soil. It is probable, indeed, that the solutions must, of necessity, be dilute, for the simple reason that they are in contact with the earth, which, like any other porous body, must tend to remove carbonic acid from its solution. Just as bubbles of gas are seen to adhere to the sides of a glass in which drinking water has been left standing for some time, or as a lively evolution of carbonic acid is caused when any rough or porous substance such as a bit of bread or

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* The results of experiments made by Mulder to determine the amounts of carbonic acid expelled from carbonic-acid water, on the addition thereto of moist earth, will be found in his "Chemie der Ackerkrume," Berlin, 1868, 2. pp. 24, 25.

† "Annales de Chimie et de Physique," 1857, 51. 290.

lump of sugar is thrown into a glass of beer that has ceased to effervesce of itself, * so within the soil there must be a constant attraction of adhesion between the solid particles of earth and the excess of carbonic acid in the solution of the acid carbonate of lime.

On the other hand, Bineau has shown that dilute solutions of the acid carbonate of lime are capable of absorbing carbonic acid from the air more rapidly and abundantly than mere water can absorb the gas; and there can be no doubt that the strength of the solutions of the supercarbonate actually obtained from soils is determined by the fact that the absorptive power of a solution of carbonate of lime for more carbonic acid, which would tend to make the solutions strong, is balanced by the surface attraction of the soil itself for carbonic-acid gas, which would tend to make the solutions weak. Bineau has shown, moreover, that the intensity of the power by which carbonic acid dissolves carbonate of lime in presence of water is far from being in direct proportion with the quantity of gas dissolved. When the amount of the latter is elevated progressively, the increased solubility of the carbonate becomes less and less manifest, until at last it may no longer be perceived. By operating in the presence of large quantities of water, he was not able to retain dissolved by carbonic acid more than four-fifths the quantity of carbonate of lime necessary to make a bi-carbonate.

I am inclined to believe that the decomposition of carbonic-acid water by the moist earths, in my experiments, is to be explained by a reference to the phenomena of adhesion above referred to; that is to say, that the decomposition is nothing more than a particular instance of the well-known surface action of solid substances upon carbonic-acid water, — the action, I mean, which is so familiarly and so well illustrated by throwing a bit of bread, or any other rough solid, into beer or other liquid charged with carbonic acid, that has been allowed to become flat by standing. In the cases where carbonic-acid water was made to pass through sharp sand, it would appear that the rapidity of the flow of the liquid through the sand was so great that only partial decomposition could occur.

On comparing the foregoing results with some experiments of similar character, made in 1860 by the Dutch chemist, Van den

Broeck,[*] I have been led to believe that the conclusions which this chemist sought to draw from his observations were not justified by his facts, nor by any evidence which has been adduced hitherto. Van den Broeck examined the waters of two kinds of wells at or near Utrecht; viz., the water of holes that had been sunk by gardeners to a depth of $1\frac{1}{2}$ to 2 metres in the surface soil, to get water for sprinkling plants, and that of certain wells of drinking-water which rises in that locality from a substratum of sand. On digging to a depth of three to five metres from the surface into the sand-bed, springs are laid bare, from which water wells up under a head sufficient to fill the hole almost or quite up to the surface of the ground.

In the waters from the sand-bed, Van den Broeck found an abundance of carbonic acid, while the water of the shallow wells in the garden soil remained clear on being mixed with lime water.

In these observations there was really nothing remarkable. The waters of simple open draw-wells, like these of the gardeners, often enough contain very little carbonic acid, while the water of springs frequently contains an abundance of it. Van den Broeck himself states that the water from the sand-bed was highly charged with carbonate of lime held dissolved by carbonic acid, and it is plain, from the mere fact that there was pressure upon the water in the sand-stratum sufficient to make it rise through the loam above it up to the surface of the ground, that it must have come from some source other than the simple percolation of rain-water through the soil which immediately overlies the sand. But to Van den Broeck, who had previously surmised that the carbonic acid of the water from the sand-bed had been leached from the loam above it, the absence of carbonic acid from the water of the garden wells suggested the thought that carbonic acid may be absorbed and held powerfully by loam, or even abstracted from its solution in water by the loam, much in the same way that potash and other bases are known to be absorbed and fixed in the soil. In order to test this idea, he took some earth from a garden that had been manured some time previously, and led a current of hydrogen gas first through the earth and subsequently through lime water, and observed that the lime water became very cloudy. He next proceeded to percolate, with pure water, a column of earth about 50 cm. high

* "Annalen der Chemie und Pharmacie," 1860, **115.** 87; and Johnson's "How Crops Feed," p. 221.

and 7 cm. thick, and observed that the filtrate remained perfectly clear when lime water was added to it. He noticed, furthermore, that this filtrate contained a considerable quantity of sulphate of lime. Finally, he percolated a similar column of earth with water that had been charged with carbonic acid at the ordinary temperature and pressure, and still found that no cloudiness appeared in the filtrate when it was mixed with an abundance of lime water; or, rather, no cloudiness appeared until after the first portions of liquid which had gone through the earth were removed, and a limit was reached, after which, the new portions of filtrate became cloudy when lime water was added to them.

It will be noticed that Van den Broeck's method of testing for carbonic acid with simple lime water was less delicate than mine, where hot lime water was used. Like Van den Broeck, I find, on percolating moist garden earth with carbonic-acid water, that a certain not very large proportion of the carbonic-acid water fails to pass through the earth at first; but I think it probable, as has been said, that this behavior is due to phenomena of adhesion. I find neither any " powerful retention " of carbonic acid by garden earth, nor any evidence that mere loam, as such, can prevent carbonic acid from passing into wells and springs. The carbonic acid in the waters of the sand-bed at Utrecht is evidently held there by the lime-carbonate whose presence has been insisted upon by Van den Broeck, and it is a question to be studied at that particular locality, how it happens that the water of the upper or garden soil is charged with gypsum rather than with carbonate of lime.

It is to be remarked, however, that considerations such as these are of subordinate interest in the present connection. The chief points thus far arrived at are, that while the percolates obtained by leaching moist loams with pure water generally contain very little if any supercarbonate of lime, appreciable quantities of this compound are contained in the percolates from most loams that have been thoroughly air-dry for some little time. Owing to the lack of dry weather in this immediate vicinity during the past summer, I have had no opportunity to test the question, whether field-dried earth will exhibit the same reactions as that stored in barrels or dried upon plates, though there would seem to be no special reason why it should not. The question could best be studied in some locality like California, where droughts are periodical; and it is in such countries, doubtless, that the good effects of

the disintegration and other reactions in the soil due to dissolved supercarbonate of lime will be most conspicuous.

Several questions of interest naturally suggest themselves, on proceeding to inquire what consequences may result from the absorption or formation of carbonic acid in dry soils, and what reactions may occur when the various constituents of soils are brought into intimate contact with a solution of supercarbonate of lime, as when rain water falls upon a dry field. For example, does the carbonic acid generated and absorbed by dry soils decompose the silicates or other compounds of lime in the soils with special facility under these conditions of dryness? In this connection, the ready conversion of sulphate of lime (gypsum) into carbonate of lime, at or near the surface of the soil, should be remembered. The fact of such conversion has often been noticed, and has been explained as follows: When a soil is warm, and highly charged with moisture, some of the gypsum contained in it is apt to be reduced to the condition of sulphide of calcium by the deoxidizing action of the organic matters in the soil; and the sulphide of calcium thus formed is decomposed in its turn on coming in contact with carbonic acid. But I find, by direct experiment, that sulphide of calcium is readily decomposed by a solution of supercarbonate of lime. Even sulphide of calcium that has been prepared in the dry way by passing a current of hydrogen gas over sulphate of lime heated to redness in a glass tube was readily decomposed with evolution of sulphuretted hydrogen, when placed in a solution of acid carbonate of lime, prepared by digesting whiting in a solution of carbonic acid in water, at the ordinary temperature and pressure of the air.

A double quantity of simple carbonate of lime will, of course, result from this reaction; viz., that formed from the sulphide, and that which was previously held in solution by the excess of carbonic acid.

There are numerous experiments which illustrate this point. De Saussure & Pictet * noticed that, after rain, the odor of sulphuretted hydrogen is perceptible upon fields that have been plastered. Schübler † found that some pure powdered mineral gypsum that was left exposed to air, rain, sun, and snow, during six months, was changed to such an extent, that 75 grains of the gypsum contained, after exposure,

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* "Gasparin's, "Cours d'Agriculture," 3me Edit. 1. 87.

† "Schweigger's "Journal für Chemie und Physik," 1817, 21. 213.

only 65 grains of sulphate and 10 grains of carbonate of lime. Coquard * found $8\frac{1}{2}\%$ of carbonate of lime in the upper parts of mineral gypsum at Aix.   As a general rule, gypsum effervesces somewhat, when treated with acid, in those parts that have been exposed to the atmosphere.

There is an old experiment of Spatzier † which deserves special mention in this connection, since it was made in an agricultural way, and for agricultural purposes.

Spatzier selected a quantity of mould that had resulted from the rotting of vegetable matters, and made therewith a small garden bed, which he dressed with a moderate dose of fresh horse-dung and then dug over, in order to thoroughly mix the dung and earth, and to leave the soil loose and mellow.   A few peas and beans were sown in the bed, and the entire surface of the soil was covered, to the depth of about a line, with finely powdered gypsum.   A portable roof was arranged, so that the bed could be protected from heavy rains, and in dry weather the bed was carefully moistened by sprinkling it from a watering pot.   At the end of three weeks, the gypsum was submitted to analysis, and it was found that the larger part of it had been changed to carbonate of lime.   The earth of the bed, also, was charged with the carbonate to the depth of half a foot, as was shown by its effervescing strongly when treated with an acid, although, at the beginning of the experiment, no trace of a carbonate could be detected, either in the earth of the bed or in the gypsum that was put upon it.   On leaching some of the earth with cold water, Spatzier found "a not insignificant quantity of sulphate of ammonia," whence he concluded that the gypsum had been decomposed by carbonate of ammonia, produced by the fermentation of the dung.   It is not impossible that, in this special experiment, some small part of the decomposition may have been due to a reaction of this kind; but it is not at all likely that the decomposition was wholly or even chiefly due to this cause.   There is every reason to believe that the deoxidizing action of the rich soil must have led to the reduction of some of the gypsum, and to the formation of sulphide of calcium, which was decomposed in due course by the acid carbonate of lime of the soil.

* " Bischof's " Elements of Chemical and Physical Geology," London, 1854, **1. 420**.

† Erdmann's "Journal für tech. und œk. Chemie," 1831, **11. 89.**

On the other hand, it is not unreasonable to expect, that in the fact of the formation, and in the reactions of supercarbonate of lime in dry soils, may be found the true explanation of the use of lime as a fertilizer upon light soils, as in the agriculture of some parts of France, and of the use of leached ashes upon our own dry soils that overlie the sand and gravel of the drift. As Professor Johnson, of New Haven, has recently insisted anew,* leached ashes are really a calcareous manure ; and the fact of their utility is unquestionably connected in some way with the carbonate of lime they contain. But if it can be shown that supercarbonate of lime is formed with special abundance in dry soils when these fertilizers are used upon them, and that, as would seem to be proved by the percolation experiments recorded in this article, this supercarbonate moves about freely in the earth on the arrival of moisture, we would have gained no small item of evidence to explain the mode of action of the lime and the ashes ; for there can be no question that the supercarbonate of lime would exert useful actions, both by setting free potash from its compounds in the earth, and by promoting the decomposition of organic matters in the soil ; for, as is well known, the solution of supercarbonate of lime is a somewhat alkaline liquid.

The power of solutions of supercarbonate of lime to decompose minerals has often been shown by direct experiments ; † and there are numerous observations of facts upon record that appear to have depended in reality upon this power of the supercarbonate, rather than upon the action of simple carbonic-acid water, to which they were referred.

The speedy formation of solutions of supercarbonate of lime, as shown by the preceding experiments, when dry soils are moistened, goes to show that the action of mere carbonic acid must be limited to the moment when the gas, or the water that contains it, first comes in contact with the soil. Subsequently, the action will be due not to carbonic-acid water, but to a solution of supercarbonate of lime. Geologists seem often to have attached undue importance to the disintegrating action of carbonic acid brought directly from the air by rain and the other forms of precipitated moisture. It is true, of

* See this Bulletin, 1. 202.

† Compare, Bischof's " Chemical and Physical Geology," London, 1859, 3. pp. 90, 91 ; and Fittbogen, in Hoffmann's " Jahresbericht," 1873–74, 1. 7.

course, that all the carbonic acid (and other compounds of carbon) in the soil, came originally from the air; but there is every reason to believe that the amount brought down directly by rain and dew is insignificant by comparison with that conveyed to the soil by way of vegetable growth and decay. It may even be true, as the experiments of Reichardt and Blumtritt * suggest, that the absorptive power of dry earths for the gas is a more efficient means than rain of bringing carbonic acid to the soil from the air. † This attraction of the gas by dry solids would seem to be of special importance, moreover, as a means of retaining in the soil the carbonic acid which is formed there by the oxidation of organic matters; *i.e.* of hindering the too rapid escape of the gas into the air.

Still another possible reaction deserves to be considered. As is well known, comparatively little supercarbonate of lime finds its way, as such, into the waters of brooks, rivers, and wells, in countries devoid of limestone, — such, for example, as the region in the vicinity of Boston. But, on the other hand, the well-waters hereabouts often contain much sulphate of lime, and the question presents itself, whether a part of this sulphate may not perhaps be derived in some cases from the reaction of supercarbonate of lime that has been formed, at the surface, upon sulphates of iron and alumina that have resulted from the oxidation, in the gravelly subsoil, of the iron pyrites which is no uncommon constituent of our rocks. So far as the mere formation of gypsum goes, it is, of course, easy to suppose that the whole of it might be formed, in the given case, from the reaction of the sulphates of iron and alumina upon silicates of lime in the earth; but it is none the less true that these sulphates would decompose supercarbonate of lime, in case it should come in contact with them, and that they must consequently tend to prevent the supercarbonate from flowing to the ocean as such. Indeed, W. Stein ‡ long ago insisted at some length that the occurrence of large quantities of carbonic acid in the waters of mineral springs may often be attributed to the reaction of carbonate of lime upon sulphates of iron and alumina formed through oxidation of pyrites in the earth.

* "Journal für praktische Chemie," 1866, **98.** 418, 476.

† Compare Mulder " Die Chemie der Ackerkrume," **1.** 182, for an excellent statement of the influence of condensation of gases by solid bodies upon the formation of soils.

‡ Leonhard & Bronn's "Neues Jahrbuch für Mineralogie," 1845, p. 804.

In this point of view, the common occurrence of sulphate of lime in natural waters manifestly supports the conception that the tendency of rain-water, which has often been noticed, to gradually wash out and remove lime from soils, is to be attributed primarily to the ready formation of soluble supercarbonate of lime in dry soils, and to the mobility of this solution. It may be true, indeed, that, because of this kind of leaching, many dry light soils may stand in greater need of calcareous manures, considered merely as plant food, than has been commonly supposed hitherto.

It is not through the downward movements, alone, of the soil-water, that the influence of the soluble lime-carbonate should be estimated; for, during the larger part of the summer season in our climate, the movement of water near the surface of most cultivable soils is upward rather than downward. Excepting times when the ground is soaked by rains, a movement of moisture towards the surface of the soil is constantly determined by the capillary power of the soil, by evaporation from its surface, and by the pumping power of the roots of vegetation, to supply the water needed for the exhalation of the leaves. But one result of this upward movement of the soil-water must be to bring the supercarbonate of lime toward the surface, where the lime-carbonate is probably often deposited in the insoluble form through evaporation both of the water and of the excess of carbonic acid.

In corroboration of this idea, I have noticed, in numberless instances, in experiments upon the growth of buckwheat in glass jars filled with various soils and sands, that in the course of two or three months, a thin, firm crust of carbonate of lime is very apt to form upon the mouths of the jars, just above the surface of the earth. This crust is insoluble in mere water, but dissolves readily, with effervescence, on being moistened with an acid; and the occurrence of the crust is so constant and general, in the experiments in question, that, in cleaning the jars after use, I long since adopted the practice of thrusting their mouths into muriatic acid for a few moments, after the insides of the jars had been washed with the acid, in order to be perfectly sure of the removal of the obnoxious crust.

In like manner, Hallier * has noticed that flower-pots of porous earthenware, and the roots of plants grown in flower-pots, are often

* "Botanische Zeitung," 1867, 25. 80; Compare Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1867, 10. 114.

encrusted with a white coating of carbonate of lime. Hallier remarks that this incrustation has long been familiar to gardeners, though usually mistaken by them for mould. It probably depends upon the decomposition of the soluble super-carbonate of lime by evaporation, which is always particularly rapid in the unglazed earthen pots.

I am indebted to my assistant, Mr. D. S. Lewis, for his attention to the details of the experiments in this research.

No. 19. — *Supplementary Note to an Article on the Composition of Pumpkins.* By F. H. STORER, Professor of Agricultural Chemistry.

BY an oversight at the time of weighing the pumpkins described in the previous number of the "Bulletin" (Vol. II. p. 81), no determinations were made of the proportion of rind as compared with the amount of flesh proper; and, when the article came to be written, it was found to be impossible to make good this defect, since no pumpkins could then be procured. It was not until a new crop of pumpkins had ripened, in the autumn of 1877, that I could determine the fact now in question. For this purpose, two medium-sized pumpkins were procured, in October, 1877, that had grown not far from the Bussey Institution; and the total weights of each were determined, together with the weights of rind and of the inside matter; *i. e.*, seeds, &c. The rind was pared to the same thickness as in the experiments of 1876 (see p. 82), and by the same person.* The results of these weighings were as follows: —

I. The pumpkin measured 22 × 17 cm.

<div>

The weight of the whole pumpkin was . . . 4.770 kil.
   ,,   ,, ,, ,, rind   ,, ... 0.210 ,,
   ,,   ,, ,, ,, seeds, &c. ,, ... 0.510 ,,
Hence the weight of flesh proper ,, ... 4.050 ,,

</div>

* My assistant, Mr. D. S. Lewis.

II. The pumpkin measured 30 × 22 cm.

    The weight of the whole pumpkin was . . . 7.536 kil.

    ,,   ,,   ,, ,, rind was . . . . 0.250 ,,

    .,   ,,   ,, ,, seeds, &c. was . . . . . 0.465 ,,

    Hence the weight of the flesh proper was· . . 6.821 ,,

The mean of the two trials gives the following percentage results: 100 lbs. of fresh pumpkins contain in round numbers about 3¾ lbs. of rind, 8 lbs. of seeds, &c., and 88½ lbs. of flesh proper.

For the sake of comparison, the amounts of nitrogen contained in the flesh proper and in the rind of these new pumpkins were determined, and the results were contrasted with those previously obtained with the pumpkins of 1876 (see p. 92). To obtain fair samples for these analyses, all the rind from both the pumpkins was dried and ground to powder; and a number of pieces (eighths) of the flesh proper were cut out methodically from different parts of the pumpkins, and likewise dried and ground. The results of these new analyses agree very closely with those previously obtained in 1876, as will appear from the following statement: On the supposition that the materials examined had all been dried at 110° C., the amount of nitrogen found in the : —

	Flesh.	Rind.
of the two pumpkins of 1877, was	1.80%	2.93%
of one of the pumpkins of 1876, was . . .	1.84	2.98
of the other pumpkin of 1876, was	2.20	3.51
Mean of the estimations of 1876	2.02	3.25 .
Mean of the estimations of 1876 and 1877 .	1.94	3.14

From all of which it appears that the pumpkins of 1877 are justly comparable with those of 1876. We can now, more readily and more precisely than was possible before, make use of the analyses given on pages 83 and 84, for the discussion of the empirical practices of our farmers in feeding pumpkins. For example, one common method of procedure is to feed out pumpkins in the autumn to milch cows kept in pastures, as an addition to or re-enforcement of the failing grass. Small pains are taken, it is true, to make the pumpkin ration definite or precise; but it is not impossible to gain a general idea of the amount of food administered in this form. Let it be assumed, for instance, that in the beginning the pumpkins are fed out at the rate of about one medium-sized one per day and per cow, and that the quantity is gradually increased until as many as four such pumpkins are given per day and per cow of 800 or 900 lbs. live weight. Since, as has been

previously stated (page 88), it is a common practice here in New England to remove the seeds from pumpkins that are to be fed to milch cows, it is fair to admit that this has been done in our supposed case.   It may be admitted furthermore, for the sake of the argument, that a medium-sized pumpkin, freed from its seeds and the stringy matter that surrounds the seeds, weighs not far from 12 lbs.; so that each of the pastured cows would finally get about 50 lbs. per day of pumpkin fodder.   But since it appears, as the mean of the experiments given above, that 100 lbs. of the flesh and rind contain $95\frac{3}{4}$ lbs. of flesh and $4\frac{1}{4}$ lbs. of rind, each of the animals would get per day about 48 lbs. of pumpkin flesh, and not far from 2 lbs. of rind. Now from the analyses recorded on pages 83 and 84, it appears that there is contained,

Lbs. of	Dry organic matter.	Albumi- noids	Carbohy- drates and fat.	Cellulose.	Fat.
In 48 lbs. of pumpkin flesh . . .	2.80	0 39	1.94	0 48	0.06
And in 2 lbs. of rind	0.25	0.06	0 12	0.07	0 01
In the 50 lbs. of flesh and rind . .	3.05	0.45	2.06	0 55	0 07

It is an easy matter, of course, to determine the amounts of albuminoids, and other constituents, that were given when the pumpkins began to be used, and at the several intermediate stages also, by dividing the above figures by four, or by whatever number may represent the quantity of pumpkins actually administered each day.

It will be noticed that the proportion of rind in the pumpkin is small as compared with that of the flesh, and that, contrary to what I had supposed when writing the original paper, there is really no special need of paying much attention to the composition of the rind in inquiries like the foregoing; that is to say, the 50 lbs. of flesh and rind might have been called 50 lbs. of flesh, in the above computation, without practical detriment to the accuracy of the result.   It is probable, as was said before, that the constituents of the rind are less easily digestible than those of the flesh; and it is certain that most animals will eat the flesh rather than the rind, when circumstances permit them to make the choice.

No. 20. — *List of Fungi found in the Vicinity of Boston.*
Part II.   By W. G. FARLOW, Assistant Professor of
Botany in Harvard University.

THE present list, which is a continuation of article No. 23,* Vol. I.,
of the " Bulletin," comprises species which have come under the
writer's observation, and which were collected either by himself or
by persons connected with the botanical department of the University.
Occasionally, reference is made to species which were found in parts of
New England, remote from Cambridge.   The species mentioned, it will
be observed, belong principally to a few orders, — those in which the
writer is especially interested; and the species of some of the orders
poorly represented in the present paper will be considered at some
future time.   The list is followed by critical notes on some of the
species mentioned in it, as well as on related species, which have been
received from different parts of the United States.

CHYTRIDINEÆ.

SYNCHITRIUM ANEMONES (DC.), Woronin.   Common near Boston,
on the leaves and stems of *Anemone nemorosa*.

SYNCHITRIUM FULGENS, Schrœter; var. *decipiens*, Farlow.   (*Uredo
Peckii*, von Thümen.)   On leaves and stems of *Amphicarpœa monoica*.
Common near Boston.

SYNCHITRIUM MYOSOTIDIS ; var. *Potentillœ*, Schrœter.   On leaves and
stems of *Potentilla Canadensis*.   Bussey Woods.

SYNCHITRIUM ———.   On young leaves of *Marrubium vulgare*.   Bussey Woods.

MYXOMYCETES.

DIDYMIUM FARINACEUM, Schrad.   Newton.   On moss.

MUCORINI.

SYNCEPHALIS SPHÆRICA, Van Tieghem.   On horse-dung.   Wood's
Hole.†

* In Vol. I., p. 486, for *Lentinus Lecontei*, Fr., read *Lecomtei*.   On p. 488, for
Hypoxylum nummularium, read *Hypoxylon*.
† The post-office address of Wood's Hole has been changed to Wood's Holl.

PERONOSPOREÆ.

PERONOSPORA OBDUCENS, Schrœter. On the cotyledons and young leaves of *Impatiens fulva*. Bussey Brook. Newton.

PERONOSPORA PYGMÆA, Ung. On leaves of *Anemone nemorosa*. Common near Boston.

PERONOSPORA FICARIÆ, Tul. On leaves of *Ranunculus acris*. Bussey Woods. Newton.

PERONOSPORA POTENTILLÆ, De Bary. On leaves of *Potentilla Norvegica*. Newton.

UREDINEÆ.

UROMYCES AVICULARIÆ, (Pers.). On leaves and stems of *Polygonum aviculare*. Newton.

UROMYCES LIMONII, (Dub.). On leaves of *Statice Limonium*. Wood's Hole. Æcidium, Uredo, and Teleutospores.

UROMYCES JUNCI, (Schw.). On *Juncus effusus*. Bussey Brook. On *Spartina stricta*. Wood's Hole.

UROMYCES EUPHORBIÆ, C. & P. On *Euphorbia maculata*. Wood's Hole.

UROMYCES STRIATUS, Schrœter. On *Medicago lupulina*. Near Bussey Institution.

PILEOLARIA BREVIPES, B. & C. On leaves of *Rhus Toxicodendron*. Common near Boston.

PUCCINIA VIOLÆ, DC. On leaves of *Viola lanceolata*. Newton. On *Viola rotundifolia*. Eastport, Me.

PUCCINIA SAXIFRAGARUM, Schl. On cultivated species of Saxifrage in the Bussey Greenhouse.

PUCCINIA XANTHII, Schw. On *Xanthium strumarium*. Gloucester, Brewster, and Wood's Hole, Mass.

  * RŒSTELIA AURANTIACA, Pk. On leaves and berries of *Cratægus Crusgalli*. Newton.

RŒSTELIA CORNUTA, Tul. On *Pyrus Americana*. Eastport, Me.

RŒSTELIA CANCELLATA, Reb. On apple leaves. Common near Boston.

RŒSTELIA BOTRYAPITES, Schw. Common on leaves of *Amelanchier Canadensis*. Near Boston.

RŒSTELIA LACERATA, Tul. Common on species of *Cratægus* and *Amelanchier*, near Boston.

RŒSTELIA TRANSFORMANS, Ellis. On *Pyrus arbutifolia*. Wood's Hole.

PODISOMA MACROPUS, Schw. Common on *Juniperus Virginiana*. Near Boston.

PODISOMA FUSCUM, Dub. Common on *Juniperus Virginiana*. Near Boston.

PODISOMA ELLISII, Berk. On *Cupressus thyoides.* Wood's Hole, Newton, and Dedham, Mass.

GYMNOSPORANGIUM CLAVIPES, Pk. On *Juniperus Virginiana.* Newton.

GYMNOSPORANGIUM BISEPTATUM, Ellis. On *Cupressus thyoides.* Newton.

UREDO FILICUM, DC. On cultivated *Cystopteris.* Bussey Greenhouse.

UREDO PYROLÆ, Mart. On *Pyrola rotundifolia.* Common near Boston.

UREDO AGRIMONIÆ, DC. Common on *Agrimonia Eupatoria*, near Boston.

ÆCIDIUM GERANII, DC. On *Geranium maculatum.* Bussey Woods.

ÆCIDIUM SAMBUCI, Schw. On *Sambucus Canadensis.* Common near Boston.

PERIDERMIUM PINI, P. On *Pinus ponderosa.* Bussey Institution.

USTILAGINEÆ.

GEMINELLA MELANOGRAMMA, Magnus. On leaves of *Carex Pennsylvanica.* Newton ; Bussey Woods.

UROCYSTIS CEPULÆ, Frost. On young onion plants. Essex Co., Mass.; Wethersfield; Greene's Farms; Ct.; and other localities.

BASIDIOMYCETES.

Sub-order *Gasteromycetes.*

GEASTER HYGROMETRICUS, P. On sandy ground. Wood's Hole, Gloucester, Mass.

LYCOPERDON CYATHIFORME, Bosc. Newton; Wood's Hole; roadsides and pastures.

PHALLUS DUPLICATUS, Bosc. Newton ; Cambridge.

PHALLUS RAVENELII, B. & C. Near New Haven, Ct. Prof. D. C. Eaton.

Sub-order *Hymenomycetes.*

TREMELLA AURANTIA, Schw. Common near Boston.

EXIDIA GLANDULOSA, Fr. Common near Boston.

GUEPINIA SPATHULARIA, Fr. Newton, on old rails.

EXOBASIDIUM VACCINII, Wor. Common on *Gaylussacia resinosa, Azalea viscosa*, and other *Ericaceæ.*

CLAVARIA MUCIDA, P. On rotten logs. Bussey Woods.

CORTICIUM CALCEUM, Fr. On fallen branches. Newton.

THELEPHORA LACINIATA, P. On the ground. Wood's Hole.

THELEPHORA PALMATA, Fr. Wood's Hole.

CRATERELLUS CLAVATUS, Fr. Gloucester, Mass. Miss Hoppin.

PHLEBIA VAGA, Fr. On flower-pots. Bussey Greenhouse.

PHLEBIA MERISMOIDES, Fr. Bussey Woods.

IRPEX PALLESCENS, Schw.　Newton.
HYDNUM FARINACEUM, P.　Newton.
HYDNUM ALUTACEUM, Fr.　Newton.
MERULIUS INCARNATUS, Schw.　Newton ; Bussey Woods.
MERULIUS PORINOIDES, B. & C.　Newton.
TRAMETES LACTINEA, B.　On trunks.　Newton.
POLYPORUS SINUOSUS, Fr.　Newton.
POLYPORUS CARNEUS, Fr.　On trunks.　Eastport, Me.
POLYPORUS RESINOSUS, Fr.　Bussey Woods.
POLYPORUS SPISSUS, Fr.　Bussey Woods.
POLYPORUS OVINUS, Fr.　Newton.
CYCLOMYCES GREENEI, B.　Newton.　On the ground under bushes.
Rare.
LENZITES RHABARBARINA, B. & C.　On a charred stump, Botanic
Garden, Cambridge.
CANTHARELLUS UMBONATUS.　In moss.　Common near Boston.
PAXILLUS ATRO-TOMENTOSUS, Fr.　Gloucester, Mass.
COPRINUS STERCOREUS, Fr.　On horse dung.　Cambridge.
AGARICUS ATRO-CŒRULEUS, Fr.　On old fences, late in the fall.
Newton.
AGARICUS VELUTIPES, Curt.　On stumps.　Cambridge.　Common.
AGARICUS VITTADINI, Kromb.　Bussey Greenhouse.　Rare.

ASCOMYCETES.

Sub-order *Perisporiaceæ.*

UNCINULA AMPELOPSIDIS, C. & P.　Common on leaves of *Ampelopsis*
near Boston.
MICROSPHÆRIA VIBURNI (Schw.)　On leaves of *Viburnum acerifolium.*
Newton.
ERYSIPHE GRAMINIS, DC.　Common on leaves of several species of
grass.
ERYSIPHE AGGREGATA (Peck).　Common on catkins of alder.

Sub-order *Helvellaceæ.*

TAPHRINA AUREA, Fr.　On young catkins of *Populus grandidentata.*
Springfield ; Newton, Mass.
TAPHRINA ALNITORQUA, Tul.　Common on catkins of alders.
TAPHRINA DEFORMANS, Tul.　On peach leaves.　Rather common
near Boston.
CENANGIUM SERIATUM, Fr.　On birch bark.　Newton.
CENANGIUM PYTHIUM, B. & C.　On *Abies alba.*　Newton.
CENANGIUM CERASI, Fr.　On wild cherry.　Eastport, Me.
PATELLARIA ATRATA, Fr.　On chips.　Bussey Woods.
PEZIZA TURBINULATA, Schw.　On red maple bark.　Newton.
PEZIZA CYATHOIDEA, Bull.　On dead stems.　Common.
MORCHELLA SEMILIBERA, DC.　Springfield, Mass.　In mossy places.

Sub-order *Phacidiaceæ.*

HYSTERIUM (TRIBLIDIUM) HIASCENS, B. & C.   Common, especially on the bark of white oak.

HYSTERIUM PINASTRI, Schrad.   Common on pine leaves.

HYSTERIUM ELONGATUM, Schw.   On dead wood.   Common.

HYSTERIUM PULICARE, Pers.   On bark.   Very common.

HYSTERIUM SMILACIS, Schw.   On *Smilax rotundifolia.*   Wood's Hole.

Sub-order *Pyrenomycetes.*

CAPNODIUM ELONGATUM, B. & Desm.   Newton; Woburn, Mass.

MICROTHYRIUM SMILACIS, De Not.   On stems of *Smilax rotundifolia.* Common.

SPHÆRIA PUNCTIFORMIS, Pers.   On dead leaves.   Common.

SPHÆRIA MASTOIDEA, Fr.   On bark of trees.   Common.

SPHÆRIA OVINA, Pers.   On dead stumps.   Newton

VALSA LEUCOSTOMA, Fr.   On branches of apple-trees.   Newton.

VALSA AMERICANA, B. & C.   On dead wood.   Common.

EUTYPE LATA, Tul.   On dead wood.   Bussey Woods.

DOTHIDEA VORAX, B. & C.   On stems of grasses.   Bussey Woods. Rare.

DOTHIDEA RIBESIA, Pers.   On dead currant-stems.

DOTHIDEA TRIFOLII, Fr.   Common on leaves of clover.

DOTHIDEA FILICINA, Fr.   Common on stems of common brake.

HYPOXYLON XANTHOCREAS, B. & C.   On stumps.   Bussey Woods. Not common.

NUMMULARIA DISCRETA (Schw.).   On dead branches.   Newton.

NECTRIA COCCINEA, Fr.   On bark of cherry-trees.   Bussey Institution. On *Sphæria morbosa.*   Newton.

NECTRIA EPISPHÆRIA, Fr.   On *Diatrype stigma.*

SPHÆROSTILBE PSEUDOTRICHIA, B. & C.   On currant twigs.   Newton.

HYPOCREA GELATINOSA, Fr.   On dead wood.   Bussey Woods.

IMPERFECT FORMS.

PESTALOZZIA TRUNCATULA, Fuckel.   On cones of *Abies excelsa.* Newton.   Common.

PHOMA UVICOLA, B. & C.   Common on cultivated varieties of grapes.

MELANCONIUM MAGNUM, Berk.   On dead sticks.   Common.

SPHÆROPSIS MAMILLARIS, B. & C.   On *Gleditschia.*   Newton.

SPOROCYBE PERSICÆ, Fr.   On cultivated cherries.   Newton.

SPHÆRONEMA SPINA, B. & C.   On dead limbs.   Common.

HELICOMA MULLERI, Corda.   On wood.   Newton.

HELIOMYCES AUREUS, Corda.   Bussey Woods.

OIDIUM FRUCTIGENUM, Schrad.   On plums.   Beverly, Mass.

STACHYBOTRYS LOBULATA, Berk.   On paper.   Cambridge.

ASPERGILLUS NIGER, Van Tieghem.   On onion bulbs.

TUBERCULARIA PERSICINA, Ditm.   On different species of *Ræstelia.* Common.

REMARKS ON THE PRECEDING LIST.

CHYTRIDINEÆ. — But little attention has as yet been paid to the American species of this order. The members of the order are unicellular parasites inhabiting the cells of both aquatic and land plants, and they are probably widely diffused. Of the marine species, *Chytridium Plumulæ*, Cohn, is common on *Callithamnion cruciatum*, Ag., and we have also observed it on *Callithamnion heteromorphum*, Ag., received from California. It has not yet been observed on *Callithamnion plumula*, Ag., in America, but it must be borne in mind that that species is comparatively rare in this country. The *Ectocarpi*, especially those which grow upon dirty wharves, are beset by species of this order, which have not, as yet, been studied on our coast. Looking at the species of *Synchitrium*, which form spots upon various land plants, we find *Synchitrium Anemones* very common, growing in company with *Urocystis pompholygodes* and *Peronospora pygmæa* on *Anemone nemorosa*. It is not unusual to find plants whose stems are swollen and blackened by the *Urocystis*, and whose leaves are frosted with the *Peronospora*, while scattered all over the plant are the minute purple dots of the *Synchitrium*. A second species of *Synchitrium* is not uncommon on leaves and stalks of *Potentilla Canadensis*, over which it is scattered in the shape of purple globules. The species differs in no respect from that mentioned by Schrœter, in Cohn's "Beiträge zur Biologie der Pflanzen," vol. i. p. 48, found on *Potentilla argentea*, to which he gives the name of *Synchitrium Myosotidis var. Potentillæ*.

Next to *S. Anemones*, perhaps the most common species near Boston is that which occurs on *Amphicarpæa monoica*, forming bright yellow dots on the surface of the leaves and stems, and which is particularly abundant near the veins of the leaves. The plant has been known for several years, but its real nature does not seem to have been hitherto suspected. In the Curtis Herbarium it figures under the names of *Uredo Leguminosarum*, Lk., collected by Peck (106), at Greenbush, N.Y., and as *Uredo Fabæ*, D.C., Georgetown, D.C., Billings (166), and Maine, E. C. Bolles (166). It was described by Peck in the 24th Report of the New York State Museum, p. 88, as *Uredo æcidioides*, and was later distributed by Von Thümen as *Uredo Peckii*, in his "Mycotheca Universalis," No. 528. The fungus bears no resemblance

to a Uredo, except in the color of the spores, which are produced free in a cell, and are not attached to any mycelium whatsoever. The fungus we have found abundant from the first of June until the middle of October, especially on plants growing in wet places. The spots vary in color from a coffee-color to a bright yellow, — the latter being more common, — and are nearly circular; so that, when the spores have been discharged, as is remarked by Peck, they bear a resemblance to Æcidia much more than to Uredo forms.

To study the development of the fungus, leaves were moistened and placed under a bell-glass, and some of the leaf-stalks were placed in watch-glasses filled with water. The spots on the leaves in three or four hours began to swell, and became reddish orange in color. A microscopic examination of the leaves showed that there was no mycelium, but that we had to do with a unicellular parasite which had invaded certain of the cells of the epidermis, causing them to swell to such dimensions as to equal in diameter two-thirds the entire thickness of the leaf. Externally, the spots rose in a hemispherical form above the surface of the leaf. A section through the discolored spots showed that the enlarged and spherically distorted epidermal cell was nearly filled by a unicellular parasite, whose contents were, at first, slightly yellow and contained numerous oil globules. Later, the contents divided into a mass of spores (zoösporangia) which, from mutual contact, were somewhat angular, and which were too numerous to count. In one instance, 200 were counted, and there were still more in the sporangium. The diameter of the spores was about .015 mm., and that of the cell in which they were contained was from .18–.20 mm.

When ripe, the sporangia burst open, and the spores, which had become reddish orange, were discharged in such quantities as to colour the water in the watch-glasses in which they were placed. For a few moments after their discharge, they assumed a spherical shape, but soon became irregularly four-angled, at the same time losing their reddish color and becoming rather transparent. About half an hour later, the contents began to divide into a number of distinct portions, and one of the four angles of the spore became more and more papillate. The internal portions became more distinctly spherical, collected at the apex of the spore, and finally burst through and the whole contents of the spore were discharged in the form of zoöspores which were of irregular

shape, and furnished with a single cilium.   The zoöspores in a very few cases were provided with two cilia, but these were rare exceptions.   Owing to other occupations, the observation of the further development of the zoospores and the inoculation of healthy leaves was not attempted.   The development of the spores just mentioned is precisely that described by De Bary and Woronin * in *Synchitrium Taraxaci.*   We had prepared drawings of our own species, but they were rendered quite superfluous by the fact that, except in the size of the spores, they were essentially the same as those already given by De Bary and Woronin.   The resting-spores of our species we have not yet been able to detect, although the plant has been carefully watched from June until October.   As before said, some of the spots appear of a browner color than the rest and we had hoped in these to find resting-spores.   In all cases, however, their microscopic structure was the same as that of the yellow spots and where the resting-spores are to be sought is still uncertain.   The species differs from *S. Taraxaci* in the much smaller size and greater number o the spores (zoosporangia), and in their bright yellow color.   The swellings produced in the leaves are more marked, and the cup remaining after the discharge of the spore more distinct.   We cannot, however, specifically distinguish the fungus on *Amphicarpæa* from that found by Schrœter on *Œnothera biennis*, and named by him *Synchitrium fulgens.*   Our plant forms spots which are somewhat larger and more highly colored than those on Œnothera, and the spores themselves are somewhat smaller than in specimens received from Dr. Stahl, gathered in Rastatt, Baden.   We would call the fungus *Synchitrium fulgens*, Schrœter, *var. decipiens.*   Possibly, when the resting-spores are found, there may be grounds for separating the species.   Being occupied with other duties, we had no time for ascertaining whether the spores from *Amphicarpæa* would produce the disease on *Œnothera.*

There is still a fourth species of *Synchitrium* found on the leaves of *Marrubium vulgare*, on which it forms small, ill-defined purple spots. The species belongs to the third of Schrœter's division of the genus (*Leucochytrium*) with whitish protoplasm.   The diameter of the spores which are solitary in the cells, and which are probably resting-spores, — at any rate, we have never succeeded in making them germinate, — is from .06–.075 mm. and there is no external swelling of

* " Ann. des Sciences," 5 série, vol. iii.

the leaf produced by the parasite, the epidermal cell attacked simply enlarging within the tissue of the leaf. The species seems to be related to *S. punctum*, Schr., but we should hesitate giving a name until more is known of its development.

In this connection, we would call attention to a species of *Synchitrium* found on the leaves and stems of *Erodium cicutarium*, collected by Dr. Edward Palmer, on the island of Guadalupe, off the coast of California. The leaves and stems are thickly beset with brownish globules, which, to the naked eye, bear a striking resemblance to the sporangia of certain ferns. The species, which is one of the most beautiful of the genus, has both spores, in the sense used in speaking of *S. fulgens var. decipiens*, and resting-spores. The epidermal cells attacked by the fungus swell up into sacks which, as in the case of *Synchitrium Myosotidis*, project from the outer surface of the leaf, but do not extend into its interior substance. The cells containing the resting-spores were, in the specimens examined, much more abundant than those containing the spores (zoösporangia), and differed from them in shape. The former were more or less regularly obovate, and contracted at the base into a pedicel of about a quarter of their own length; the latter were spherical, without any pedicel, and the neighboring epidermal cells grew up so as to form a small cup around the lowest portion, about four-fifths of the cell, however, being entirely free, and rising above the adjacent cells. The zoösporangia were numerous, brownish-yellow in color, and rather larger than those of *S. fulgens*. The material received was not in a condition suitable for the study of the development. The cells containing the resting-spores were about .2 mm. long, including the pedicel and the surface of the upper portion, instead of being smooth as in *S. Myosotidis*, was marked by a number of blunt papillæ, whose number was variable, but averaging about twelve. In section it could be seen that the cell wall was much thinner in the papillæ than in other places, and it is altogether probable that the spores are discharged by the rupture of the apex of the papillæ. The resting-spores are sometimes solitary, but more frequently there are two or three in a cell. They measure .065–.075 mm. by .04–.05 mm., are brownish in color, oval in shape, and have a cell wall of considerable thickness, which is composed of two distinct layers, the outer of which is more deeply colored than the inner, and is slightly roughened on the surface. As far as we can

ascertain, the species has not been, as yet, described. We would propose for it the name of *Synchitrium papillatum.*[*]

PERONOSPOREÆ. — Of the species of *Cystopus*, mentioned in the " Bulletin," vol. i. p. 429, *C. cubicus*, Mart., has been found to be common on salsify (*Tragopogon porrifolius*) near Boston ; in fact, so common as to excite fears in the minds of farmers that the crop might be destroyed. *Cystopus Bliti*, Bivon, common on species of *Amaranth*, has been observed on *Acnida cannabina*, L., in brackish marshes in Cambridge, both conidia and oöspores being abundant.

Of the species of *Peronospora*, several have been added to the list of those previously known to inhabit the United States. *P. pygmæa*, Ung., is common on the leaves of the wood anemone (*A. nemorosa*) in early summer. The form found in this country does not differ from the type as it occurs in Europe. With regard to the germination of the conidial spores, the following was noticed. When entirely submerged, the whole contents of the spore are first discharged, and then the germinal tube grows from one end of the discharged mass. When, however, the spores lie on the surface of the water, the germinal tube grows directly from the spore itself. Another species not uncommon on *Ranunculus acris* is *P. Ficariæ*, Tul., which bears a close resemblance to *P. effusa*, Grev., of which it appears like a dwarf form. Both conidia and oöspores were found on *P. acris*, and the American form does not differ from the European type. The same is true of a third species, *P. Potentillæ*, De Bary, found on seedlings of *Potentilla Norvegica*, growing in a wet meadow at Newton, late in October, 1877. The fungus was luxuriant, and both conidia and oöspores were abundant.

In Vol. I. p. 428, of the " Bulletin," reference was made to a *Peronospora* on *Plantago major*, found at Newton, Mass. Since then we have been able to compare the Newton specimens with specimens of *P. alta*, Fuckel, and find that they are the same species. We must confess, however, that *P. alta* approaches very closely to *P. effusa*, Grev., to which the Newton fungus was at first referred. The New-

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[*] *Synchitrium papillatum*, n. sp. Resting-spores .065–.075 mm. by .04–.05 mm., 1–3 in a cell, brownish, epispore roughened ; epidermal cell externally elongated into an obovate, pyriform sac, surface raised in blunt papillæ ; zoösporangia brownish, very numerous, in spherical cells. On leaves of *Erodium cicutarium* collected on the Island of Guadalupe, California, by Dr. E. Palmer.

ton specimens contained oöspores, but we have not found them in European specimens. As far as we can ascertain, *P. alta* differs from *P. effusa* principally in its taller and less frequently branching conidial-stalks.

The most interesting *Peronospora* recently recorded in the United States is *P. obducens*, Schrœter. It was first observed by Mr. B. D. Halsted on the cotyledons of *Impatiens fulva*, Nutt., growing in the Bussey brook, May, 1876, and found the following week, by the writer, at Newton, Mass. Since then, the species has been observed several times by the writer on *Impatiens fulva*, the under surface of whose cotyledons and young leaves it covers with a thick white down. The fungus disappears early in June; the seedlings which are severely attacked being killed at once, and others recovering from the attack, so that the fungus is no longer to be seen, at least on the surface, after the cotyledons have fallen. The mycelium of the fungus is distinctly seen throughout the cotyledons, and, owing to the frequent inter-cellular spaces, presents a more striking appearance than that of almost any other species of *Peronospora* with which we are acquainted. The hyphæ are broad, and branch in all directions. Haustoria are numerous, and of a sphæroidal shape, attached by a narrow neck as are the haustoria of *Cystopus candidus*, from which, however, they differ in being very much larger. The ordinary diameter of the haustoria is .01 mm., but, as they grow old, they become, not unfrequently, .02 mm. in diameter and the cell wall, which is at first thin and colorless, becomes thick, yellow, and roughened, so that, when rather thick sections of the leaf are examined, the first impression is that one has before him a number of small-sized oöspores.

The mycelium, which is most beautifully seen in the cotyledons and first pair of leaves, is also found in the young stem, but is by no means so striking there as in the less compact tissue of the cotyledons. The conidia are borne on stalks which are about .3 mm. high, and which penetrate, few in number, through the stomata; the dense felt produced by the fungus on the lower surface of the cotyledons being caused by the great number of stomata, through which the conidial stalks make their way, rather than by the number of stalks which pass through each stoma. The conidial stalk rises nearly straight, and gives off three or four principal branches at right angles. The latter again branch in a similar manner three or four times, the ultimate divisions being some-

what awl-shaped. The conidial spores are broadly oval, and very slightly papillate at the apex. When sown in water, the contents divide into a number of zoöspores, from six to about twelve, which are discharged, swim about by means of two cilia, and finally come to rest, as in the manner already described in *Peronospora viticola* and other species. We have never found ripe oöspores in the present species, and only once have we found young ones in the stalk of *Impatiens;* although we have examined the cotyledons carefully, especially those which had fallen to the ground. As we have said, the fungus disappears very rapidly, and the fallen cotyledons, in which one would naturally look for oöspores, are recognizable only for a few days.

The species is apparently the same as that described by Schrœter, in " Hedwigia," September, 1877, found by him growing on *Impatiens noli-tangere*, L., near Rastatt, Baden, in May, 1875. In no important respect does our plant differ from Schrœter's description of the fungus to which he gives the name of *Peronospora obducens.* The species is evidently related to *P. nivea*, Ung., and *P. viticola*, B. & C. The haustoria remind one of the description of those of *P. densa*, Rab., given by De Bary. Some penetrate directly into the interior of the leaf-cells, while others simply form spherical depressions in them, and the "granule" in the interior is very distinct in old specimens. The conidial stalks, while branching in a general way like those of *P. viticola*, are less dense, and more pyramidal in outline.

At the same time that the fungus was found on *Impatiens*, a species of *Peronospora* was also gathered on young plants of *Eupatorium purpureum*, but in very small quantities. . The seedlings, which were not over four or five inches high, were gathered and placed in glass bottles under a bell-glass, to favor the growth of the *Peronospora*, but we were not successful in making the fungus appear on more than half-a-dozen leaves. The species is interesting from the fact that it bears an exceedingly close resemblance to *P. obducens*, and may perhaps prove to be the same species. At any rate, it was not like any of the other species hitherto observed on *Compositæ*. The mycelium was quite the same as that of *P. obducens*, but, owing to the denser structure of the *Eupatorium* leaf, did not show as distinctly. The conidial stalks were like those of *P. obducens*, and the spores were similar, but larger and rather broader at the base. No oöspores were observed. Unfortunately, although several attempts

were made, we were not successful in making the conidia germinate, and we could not consequently attempt the inoculation of young *Impatiens* plants with the spores of the *Peronospora* on *Eupatorium.* With the imperfect material at our disposal, it is impossible to say precisely what the species is, whether new or not. From its form alone, we should think it only a variety of *P. obducens,* approaching *P. nivea.**

In the Twenty-eighth Report of the New York State Museum of Natural History, bearing the date April, 1876, is a species described by Mr. Peck under the name of *Peronospora Geranii,* on *Geranium maculatum.* It may be that this is the same species mentioned in the "Bulletin," Vol. I. p. 426, and referred to *P. nivea,* Unger.; but as there is no mention made of the oöspores, and as the branching of the conidial stalks is described simply as divaricate, we cannot venture to express any opinion. Mr. Peck states that the apices are not swollen, but considers the species related to *P. gangliformis* which could hardly be the case, as the apices of that species are markedly swollen, De Bary describing them in the following words: "dichotomiæ ultimæ apice inflatæ in vesiculam tympaniformem, v. turbinatam v. subglobosam."

In the same Report, Mr. Peck mentions *P. obliqua,* Cooke, as occurring on *Rumex crispus,* at North Greenbush, N.Y. We are much indebted to the politeness of Mr. Peck for specimens of the New York plant, and also to Mr. M. C. Cooke, who kindly communicated English specimens; and we have been able to recognize the species as one which we have found, from May to November, on leaves of *Rumex crispus* at Newton, and also in August on leaves of *R. obtusifolius* at Brewster, Mass. We have carefully examined fresh specimens of the fungus, which was allowed to develop under glass in the laboratory, that the spores might be seen both when young and old and we are compelled to differ from the opinion held by the above-named gentlemen, and consider that the species is not a true *Peronospora,* but a *Ramularia.* The mycelium of the fungus is found in all parts of the leaf, but especially in the round dark spots recognized by the naked eye. It is very small, .002 mm. in diameter without haustoria, and is quite unlike the mycelium of a *Peronospora.* The mycelium makes its way through the stomata into the air, a large number of threads

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* Since the above was sent to press, *Peronospora Cyparissiæ,* De Bary, was found on leaves of a *Euphorbia* collected by Mr. J. B. Ellis, Newfield, N. J.

passing through each stoma, and appearing to the naked eye as minute white specks on the discolored spots of the leaf. The arrangement often appears concentric; and, if cultivated in the house, the concentric rings grow larger and larger, the outermost being the most distinct.

The spores easily fall from their attachments; and, unless care is taken, all but the youngest drop off before they can be examined under the microscope. They are frequently of an oval shape, attached either at the end of the stalk, or often a little to one side; and when of any size they form an angle with the direction of the stalk, which warrants the name *obliqua.* When fully ripe, however, the spores are not ovate or pyriform, but long and narrow, and not simple, but septate with from one to three partitions. There are not usually any constrictions at the partitions, and the spores are rarely moniliform. Sometimes the spores are very long and narrow and bent in different directions, and occasionally some of the upper ones branch. The species scarcely differs, if it differs at all, from the fungus described by Fresenius, in the " Beiträge zur Mykologie," p. 88, Pl. XI. figs. 29–32, under the name of *Ramularia macrospora.* It is almost impossible to recognize the species of *Ramularia,* which have been described, from the spores alone, because, as is seen in the present case, the spores may vary from short and pyriform to long and fusiform in the same species. As in *Peronospora,* the hyphæ pass through the stomata in tufts in many of the species of *Ramularia.* The latter genus is not well defined scientifically, as is the case with *Peronospora,* but is only a form-genus in which are placed fungi resembling one another in shape, but which may be only states of other fungi. Recently Schrœter * has hinted that some of the so-called *Ramulariæ* may be connected with species of *Entyloma.* Such is, however, not the case with the species on *Rumex,* as far as our specimens show. Tulasne † suggests that some nearly related species accompany species of *Stigmatea,* of which he mentions that one occurs on *Rumex.* It may be that our species has some connection with *Sphæria. Rumicis,* Desm., but we have not been able to trace it. We found *Cylindrospora concentrica,* Grev., which Schrœter ‡ says includes *Ramularia*

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* "Beitrage zur Biologie der Pflanzen," Vol. II. part III. p. 485.

† " Select Fung. Carp." Vol. II. p. 292.

‡ L. c. p. 481.

Lamii and *Ram. Urticæ* of Fuckel, growing on *Oxalis acetosella* at Eastport, in September, 1877, where it seemed to be common.

USTILAGINEÆ. — There has been received from Professor C. E. Bessey of Ames, Iowa, some interesting members of this order: viz., *Thecaphora aterrima*, Tul., on an undetermined species of *Carex*, *Sorosporium bullatum*, Schrœter, on *Panicum Crus-Galli* and *Ustilago neglecta*, Niessl., on *Setaria glauca*. With regard to the onion-smut described in the Mass. Agric. Report for 1877, opinions vary. In an article by Prof. Fischer von Waldheim, entitled "Les Ustilaginées et leurs Plantes Nourricières," *Urocystis Cepulæ* is kept distinct from *U. magica*, Pass., and *U. Colchici*, Tul. Schrœter * states that he found specimens of *U. Colchici* on onion, in the herbarium at Strasburg, and considers that *U. magica* is not distinct. He remarks that the *Urocystis* on onion in America has not been described, which would indicate that his article must have gone to press before the publication of the description in the Mass. Agric. Report. In the last number of the "Bulletin," we stated that *U. Cepulæ* and *U. magica* seemed identical, but differed from *U. Colchici*. The difference, though slight, seemed constant, and how far it depends on the different texture of the foster-plants must be settled by cultures.

UREDINEÆ. In the present list the *Roesteliæ* and *Podisomata* are kept distinct. As the views of the writer with regard to the two genera are stated fully in another paper, in the present list it was thought best to retain arbitrarily the specific names generally adopted in this country. Of species growing on coniferous trees, there occurred on young seedlings of *Pinus ponderosa* cultivated at the Bussey an interesting form of *Peridermium*. The disease showed itself in the latter part of May, covering the stems of a great part of the plants under cultivation. The form was that known in Europe under the name of *Peridermium Pini var. corticola*, which is fully described by Hartig.† In the specimens growing at the Bussey, no spermagonia were noticed. We have received the same species from Mr. J. B. Ellis, growing on pines near Newfield, N. J. In the Curtis collection are specimens from Santee River, S. C., collected by Ravenel, and from Alabama, collected by Peters (1242). The name attached to the above-named specimens is *Peridermium Pini* but within the last

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* L. c. p. 878.

† " Wichtige Krankheiten der Waldbäume," p. 71.

few years the disease has been generally known in this country under the name of *Peridermium cerebrum*, Pk., described in the 25th Report of the "State Botanist" of New York. As occurring in New Jersey and Massachusetts, the disease, does not differ from the corticolous form of *Peridermium Pini* of Europe, which has at times all the characters assigned to *Peridermium cerebrum*. Hartig thinks it doubtful whether the corticolous and acicolous forms really belong to the same species, but they are not generally separated by European mycologists. In New England the fungus seems to be rather rare, and we have never seen the acicolous form. The plants attacked at the Bussey were all raised from seed sent from California, and were not over two feet in height. Most of the plants apparently recovered later in the season, but the following year the greater part of them died.

In this connection, we would mention a superb specimen of *Peridermium* received from California, where it was found by Dr. H. W. Harkness, on *Pinus insignis*, and which was also collected during the last summer by Sir J. D. Hooker. The branches affected were swollen and distorted, and in the specimen received from Dr. Harkness the swollen surface was so covered by the æcidia that the surface was completely yellow, the bark being nowhere visible. A microscopic examination shows that the spores and peridial cells do not essentially differ from those of the species found at the Bussey. Without having seen Californian specimens in a young state, it would be presuming too much to say that the species of the West coast is the same as that of the East; but the variation of the fungus, in Europe, would lead one to be cautious in accepting species which depend for their characters rather upon luxuriance of growth than distinct anatomical characters. The fungus, if new, and that point can only be well settled by securing young specimens, should bear the name of *Peridermium Harknessii*, which was proposed by Mr. J. P. Moore, in the San Francisco Microscopical Society, in 1876. In this connection it should not be forgotten that the acicolous form of *Peridermium Pini* occurs on *Pinus insignis* in California.

The rare fungus mentioned in the "Bulletin," Vol. I., No. 23, on cones of *Abies excelsa*, at Newton, *Æcidium conorum Piceæ*, Rees, has recently been received from Colorado, where it was found on cones of *Abies Engelmanni*, by Mr. T. S. Brandegee.

In the region of Boston, there are found two species of *Phragmi-*

dium.   P. mucronatum, Pers., is very common on both wild and cultivated roses; and the same species, sometimes known under the name of *P. incrassatum*, Lk., is found on both wild and cultivated species of *Rubus*, on which it forms more dense black patches than when growing on roses.   Equally common is *P. Potentillæ*, Pers. (*P. obtusum*, K. & S.) which is abundant on *Potentilla Canadensis*, where it is usually found mixed with *Sphæria Potentillæ*, Schw.   The species is generally known as *Aregma triarticulatum*, B. & C.; but we agree with Schrœter in thinking that the species is not distinct from *P. Potentillæ*, Pers.   When young, the spores appear sometimes club-shaped, but when ripe they are as regularly elliptic as are the spores of *P. Potentillæ*.   We cannot, however, agree with Schrœter,[*] in thinking that *P. speciosum*, Fr., is not distinct.   Apart from the extraordinary habit, which to the eye resembles much more that of a *Dothidea* than a *Phragmidium*, the spores are distinguished by being almost entirely smooth, tipped with a minute point, and attached to very long pedicels.   The number of divisions of the spores is about 6–8.   Schrœter is in error in supposing that this striking species was unknown to Schweinitz.   It is mentioned in the " Synopsis Fung. Am. Bor.," p. 306, No. 3084, and referred to *Seiridium marginatum*, Lk.   Schweinitz remarks that the species exactly agrees with the figure of Nees,[†] which extraordinary statement is explained by the reference to the " lentem quam minime augentem."   Streinz [‡] has increased the confusion by giving *Seiridium marginatum*, Nees, as a synonym of *Aregma (Phragmidium) speciosum*, Fr., whereas Fries § distinctly states that his species is the *Seiridium marginatum* of Schweinitz and not of Nees, and gives as a locality only North America, while Streinz mentions as well Central Europe.   Schweinitz, in the work above mentioned, describes a second species, *Seiridium Smilacis*, which he says is common on species of *Smilax* at Bethlehem. We have examined an original specimen of the so-called *S. Smilacis*, and find that it is identical with *Phragmidium speciosum*.   Furthermore, the supposed twig of *Smilax* is exogenous and not endogenous, and evidently belongs to some Rosaceous shrub.   Of course, it is

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[*] "Hedwigia," Vol. XIV. p. 166.
[†] " Syst. der Pilze und Schwämme," Pl. I. fig. 19.
[‡] "Nomenclator Fungorum," p. 181.
§ " Syst. Mycolog." III. p. 496.

impossible to speak with assurance unless one has had a long experience in the examination of rose stems, but it seemed as though the specimen examined belonged to *Rosa lucida*, or some nearly related species. *Phragmidium speciosum* has not been collected near Boston, as far as we know; but it is not uncommon in the Middle States, and extends at least as far West as Iowa, where it was collected by Professor C. E. Bessey.

The fungus on *Amorpha*, named by Berkeley and Curtis *Puccinia Amorphæ*, is made by Schrœter * the type of a new genus, *Uropyxis*, distinguished mainly by the presence of a gelatinous covering to the spore. The fungus is not uncommon wherever the species of *Amorpha* are found, but it does not occur in the vicinity of Boston. It is found from South Carolina (Ravenel) to Iowa (Professor Bessey), where it occurs on *A. canescens*, and, if we are not mistaken, on *A. fruticosa*, and to San Diego, Cal. (Cleveland), where it occurs on *Amorpha Californica*. We have received from Professor Bessey *Amorpha* leaves on which were both Uredo and Teleutospores. The Uredo spots are yellowish, and surrounded by a border of closely-packed, club-shaped paraphyses, as in the Uredo of *Melampsora salicina*. The Uredo spores are oval, covered with slight projections, and about .02 mm. in diameter. As the Uredo first appears, the paraphyses are short; but, as the teleutospores succeed the Uredo spores in the spots, the paraphyses grow much larger. The gelatinous portion in the young spores is very large compared with the dark mass of the central portion, but, as they ripen, is reduced to a thin coat covered with slight projections, which ruptures, on the application of potash, a part remaining attached to the lower end in the form of a cup. It might be well to inquire whether *Æcidium Fraxini*, Schw., is a stage of this fungus. It is common in the regions where *Puccinia Amorphæ* is found. Experiments on this point cannot be carried on at Cambridge, where it is not possible to get fresh material for study. An interesting *Puccinia* was sent to us, in March, 1875, by Mr. D. Cleveland, of San Diego, Cal. It was growing in company with an Æcidium on *Malvastrum marrubioides*. The *Puccinia* formed small round spots of a blackish-purple color, which were raised convexly above the surface of both sides of the leaf. The Æcidia on the under surface were in dense clusters, with orange-colored spores about .02 in diameter. The spermagonia

* "Hedwigia," Vol. XIV. p. 165.

on the upper surface of the leaf were sub-epidermal and comparatively large. The teleutospores were brownish, on long pedicels, rather broadly ovate, only slightly constricted at the septum, and pointed at the extremities. They measured from .055 to .075 mm. in length, by about .02 mm. in breadth. The teleutospores were not unfrequently three and even four celled. The question arises whether this is not a form of *Puccinia Malvacearum*, Mont. It differs in the color of the spores, which, in *P. Malvacearum*, are decidedly yellow, and also more slender and acute than in our form. *P. Malvacearum*, moreover, is not, as far as our experience goes, accompanied by an accidium. The spores would warrant us in supposing the species distinct, but, although the difference is as great as that found in the case of many species supposed to be specifically distinct from one another, yet we must confess that we cannot help suspecting that the European form with which we are familiar, belongs to the same species as the Californian plant. We would call the fungus *P. Malvacearum var. Malvastri*, and consider that it differs from the type in having blunter and darker colored spores. We found at Wood's Hole in September, a *Puccinia* on *Proserpinaca pectinacea*, which in external appearance resembles *Puccinia Epilobii* DC., but which differs from it in the shape of the spores, which are longer and more acute. We are again in doubt whether to call it a new species or a variety of *P. Epilobii*. We are inclined to favor the latter view.

The genus of *Uredineæ*, which is most perplexing, is without doubt *Uromyces*. This arises from two reasons. First; because all the single-spored *Uredineæ* were formerly placed in the genus *Uredo*, and it is now difficult to say whether any *Uromyces* is new, because it may have been already described by older writers, under the name of a *Uredo*; and secondly,— and this is a point to which sufficient attention does not seem to have been paid by mycologists, — because in some species of *Puccinia*, where the ripe teleutospores are two-celled, there occurs an interval when they are unicellular, and it is then impossible to say certainly whether we have before us a genuine *Uromyces*, or the undeveloped state of some *Puccinia*. However easy it may appear abstractly to settle this point, in practice it is often difficult; and undoubtedly several species of *Uromyces* have been described from what were only undeveloped *Pucciniæ*. In this connection, we may mention two species found, one on *Brizopyrum spicatum* at Falmouth,

Mass., and the other on *Spartina stricta* at Wood's Hole, Mass. Both of these grasses were partly submerged at high tide. The species on *Spartina* was first observed in August, when Uredospores were abundant. They were large, bright orange, and measured .03 mm. They germinated and flourished equally well, whether sown in salt or fresh water. The teleutospores were one-celled, .025 mm. by .015 mm. in size, oval, and much thickened at the apex, which was acute. We have also found the same species growing on *Juncus effusus* on the banks of the Bussey Brook. The specimens on *Juncus*, which were gathered in April, contained naturally only teleutospores; which, when placed under a bell-glass, produced at once promycelia and sporidia, showing that the fungus was in a normal condition. A comparison with a Schweinitzian specimen of *Puccinia Junci*, Schw., shows that it is the same as our specimens gathered at the Bussey. There is a sketch of the spores accompanying the specimen, showing that Curtis recognized their unicellular character; but there is added in pencil the remark that the spores are apparently young. That could not have been the case with our specimens, which had lasted through the winter, and which were ripe, as shown by the fact that they at once germinated. Together with Schweinitz's specimen, is one collected by Sprague, No. 5310, also on *Juncus effusus*, in which the spores are like those in the specimen of Schweinitz, except that occasionally one is found two-celled as in a true *Puccinia*. The same species was found by Howe in New York, and Dr. Michener in Pennsylvania; and recently we have received the same species on *Juncus mertensianus* collected in Colorado by Mr. T. S. Brandegee. *Puccinia Junci*, Schw., described in the " Syn. Fung. Am. Bor." No. 2913, seems to have escaped the notice of most botanists. It is mentioned as a *Puccinia*, in the 22d Report of the " Botanist of New York State." Temporarily all the specimens mentioned, whether on *Juncus* or *Spartina*, must be referred to *Uromyces Junci* (Schw.). It may be asked whether there is not some older European name. Certainly the same species occurs in Europe. We have a specimen collected by Roussel near Paris, in 1843, marked *Puccinia Junci*, Chevalier, Flore de Paris. We are not familiar with the fungus on *Dactylis* mentioned by Schrœter, in "die Brand und Rostpilze Schlesiens" as *Uromyces Dactylis*, Otth.; but the description indicates that it is very much like *Uromyces Junci* (Schw.). In " Grevillea," June, 1877, p. 152, Cooke

speaks of *Trichobasis Junci*, Str., on *Juncus* at Portland, Me. This may refer to the *Uredo* of *U. Junci*. *Uredo Junci*, Str., if that is what is meant by *Trichobasis Junci*, Str., has been referred by writers to *Puccinia caricina* and *P. Graminis*, whether correctly or not we do not know, for European writers do not agree upon this point.

The *Uromyces* on *Brizopyrum spicatum* differs from that on *Spartina*, in several respects. The Uredo spores are smaller, about .02 mm. in diameter, and the teleutospores are about .026 mm. in diameter, and are nearly spherical, not having the thickened· and pointed extremity. It will be noticed that the relative size of the Uredo and Teleutospores is reversed in the two species. The form on *Brizopyrum* was first collected by Olney (1853), Newport, R. I., Herb. Curtis, and in "Grevillea," December, 1874, the specimen is quoted under *Puccinia Graminis*, and the fungus is said to be "in a young abnormal state." No. 1519, on Andropogon from South Carolina, mentioned in the same connection is to be referred to *Uromyces Junci*. By the kindness of Mr. Peck we have been enabled to examine specimens collected by Hon. G. W. Clinton, on *Brizopyrum* at Shelter Island, New York. The fungus, which is the same as that found at Wood's Hole, is referred to *Uromyces Graminum*, Cooke, in the 28th Report of the "Botanist of New York State." Whether to consider the fungus as a true *Uromyces*, or simply as an undeveloped form of *Puccinia Graminis*, seems to have been differently answered by different writers. We did not succeed in making our Wood's Hole specimens germinate, but they were gathered rather early in the season. Occasionally one finds a teleutospore which is two-parted like a *Puccinia ;* not, however, like a spore of *P. Graminis*, but, if any thing, more like *P. caricina*. But, an occasional division of a *Uromyces* spore is not sufficient to remove the species to *Puccinia*. By a similar reasoning, we should be obliged to transfer the *Puccinia*, which are not unfrequently three or even four celled, to *Phragmidium*. It seems to us that Mr. Peck is right in considering his plant a *Uromyces*, and not an undeveloped *Puccinia*. Most certainly it cannot belong to *P. Graminis*, and it is extremely doubtful whether there is any connection with *P. caricina*. *Uredo caricina* DC.,. is considered by Leveillé a Uromyces (Ann. des Sciences, Sér. 3, Vol. 8, p. 375), but if we are to trust French specimens of that species in Herb. Curtis it is not the same as the American fungus above mentioned. Neither, as far as we know, can the

species be referred to any Schweinitzian form. It seems to us, however, doubtful whether *Uromyces Caricis*, Peck, of Von Thümen's "Mycotheca," No. 746, is distinct from the form on *Brizopyrum*. If it is, the difference must consist in the slight roughness on the wall of the spore, which is not, however, mentioned by Peck as a specific mark, in the 24th Report of "New York State Botanist."

A *Uromyces* abundant at Wood's Hole on *Statice Limonium* is identical with *Uromyces Limonii* (Dub.). Æcidia, Uredo, and Teleutospores were noticed. The æcidium was described as a new form in the 23d Rep. of the "New York State Botanist," but seems to be the same as *Æcidium Statices*, Desm., of Europe. The same fungus is represented in the Curtis Herbarium by a specimen marked *Uromyces Statices*, B. & C., from Marc Isd. Cal. U. S. Expl. Expd. There is also a *Uromyces* common on different species of *Euphorbia* throughout the Eastern United States, which has received several names. It was apparently first seen by Schweinitz, and referred by him in "Fung. Car. Sup." No. 474, to "*Uredo scutellata*" and afterwards in "Syn. Fung. Am. Bor." No. 2846, to *Cæoma punctuosum*, Lk. It was afterwards described in the "Fungi Cubenses" as *Trichobasis Euphorbicola*, B. & C., No. 598 (Wright 720) and later still in the 25th Rep. of the "Botanist of New York State" as *Uromyces Euphorbiæ*, C. & P. An examination of a Schweinitzian specimen shows that the fungus is the same as that common from New England to Texas on different *Euphorbiæ*, but it is not as Schweinitz supposed the *Cæoma punctuosum* of Link. Neither is it, as Curtis states in his list, a form of *U. apiculosa*. Curtis at one time apparently considered the fungus to be the *Æcidium Euphorbiæ hypericæfoliæ* of Schweinitz, which could not have been the case if Schweinitz's description in "Syn. Fung. Am. Bor." No. 2890 is correct. We have not, however, seen a specimen of the last named species. The first definite description of the fungus is that given by Berkeley in "Journ. Linn. Soc." Vol. X. p. 357. The specimen in Herb. Curtis, No. 720, contains both Uredo and Teleutospores, and the species is certainly the same as that afterwards described as *U. Euphorbiæ*, C. & P. *Uromyces myristica*, B. & C., on *Euphorbia bicolor*, Texas, we cannot on careful examination consider distinct. The American fungus needs to be carefully compared with *Uromyces scutellatus*, Lev. What is, at present, generally known in Germany as *U. scutellatus*, Lev., differs from the American form in having

larger spores, which are covered with flexuous ridges rather than papillæ. *U. excavata*, as far as we know, has not with certainty been observed in America. Neither has the common *Melampsora*, found on *Euphorbiæ* in Europe, been observed near Boston. There is, however, a *Melampsora* on *Euphorbiæ* in the Southern States, which seems to differ from that of Europe.

A *Uromyces* is found on *Asclepias Cornuti*, which does not agree with *Uredo Asclepiadis*, Schw. It seems to have been first mentioned in the 23d Report of the "Botanist of New York State," and described as *Trichobasis Howei*. A species, *Uromyces Asclepiades*, is described by Cooke, from Cape Elizabeth, Me.; but the description does not agree with the species found near Boston, in which the spores are marked with small protuberances. *Uredo Iridis*, Schw., which is common on *Iris versicolor*, was watched from June to February, in hopes of discovering the teleutospores, but without success. Uredospores are produced all summer, and in the autumn they fall from their attachments, and are not succeeded either by a *Uromyces* or a *Puccinia*. It is difficult to understand in what respect *Trichobasis Iridecola*, Peck., differs from *Uredo Iridis*, Schw.

GASTEROMYCETES. — On page 433, Vol. I. of the "Bulletin" we mentioned *Phallus indusiatus*, Bosc, as occurring near New Haven. We intended to have written *P. duplicatus*, Bosc. We were led to give that name to the specimens sent by Professor Eaton, from their resemblance to No. 5619 of the Curtis herbarium collected by C. Wright (244), in Connecticut. Although the specimen referred to is labelled *P. duplicatus*, it cannot be that species, as there is no veil. There grows not unfrequently about Boston a species which precisely corresponds to Bosc's figure of *P. duplicatus*, with a rather short, thick stipe, and a short veil which hangs closely about the stipe. There is also another form which approaches more nearly to *Phallus indusiatus*, Vent., which occurs in Cambridge. In this the veil is longer, the meshes are larger, and, instead of hanging close to the stipe, it is funnel-shaped. *Phallus indusiatus* of tropical America is not very well defined, and Schlectendal * apparently had very little reason for distinguishing such a number of species of the sub-genus *Hymenophallus* from a comparison in several instances of plates of rather a doubtful character. We believe that the form found in Cam-

* "Linnæa," Vol. XV.

bridge with the expanded veil is nothing more than the fully developed *P. duplicatus*, and not the true *P. indusiatus* of more southern countries. As to the specimens from New Haven, they certainly are not *P. indusiatus* nor *P. duplicatus*, nor can they be *Corynites Curtisii*, Berk., also found by Wright in Connecticut, which, although resembling them, has an imperforate apex. They are rather to be referred to *Phallus Ravenellii*, B. & C., to which also belongs No. 5619, C. Wright of Herb. Curtis. The New Haven specimens are four or five inches high, slender, and the surface of the pileus is not traversed by a coarsely toothed net-work, but is granular. The pileus is more or less bell-shaped, an inch or an inch and a half long, and there is a rudiment of a veil not more than a quarter as long hanging just underneath the pileus, and fastened at the top of the hollow spongy stipe. The volva is rather small. *Phallus rubicundus*, Bosc, differs in having the stipe red and the pileus grooved at the apex.

Lycoperdon cyathiforme, Bosc, is one of the most striking species of the order found near Boston, and occasionally is half as large as a man's head. We have also received the same fungus from Mr. C. C. Frost, of Brattleboro', Vt., under the name of *Lycoperdon albo-purpureum*.

HYMENOMYCETES. — The *Ericaceæ* of this country, as well as of Europe, are infested by a fungus, *Exobasium Vaccinii*, Woronin, which produces deformities which vary with the plant on which it is growing. As might be expected, considering the number and variety of the *Ericaceæ* in New England, we have the fungus with us assuming many different forms. The common form of Europe abounds with us in June on *Gaylussacia resinosa*, the common whortleberry, and on the blueberries. We have also found it on cultivated species of *Vaccinium*, growing in the Bussey green-house. The leaves become covered with a white powder, and the young fruit and twigs are swollen, sometimes to three or four times their natural size, and are of a pleasing pink color, covered with a white powder. In this form of the fungus, conidia are very abundant, and basidiospores less so. Another form corresponding to the *Exobasidium Rhododendri* of Fuckel, occurs on the leaves of *Azalea viscosa*, where it causes a peculiar disk-like or cup-like deformity, which has been described as *Exobasidium discoideum*, Ellis.* The same fungus, when it occurs on the floral organs

* "Bulletin of Torrey Club," Vol. V. No. 11.

of the *Azalea,* produces the succulent mass known in some parts of the country as May apples, why, it is difficult to say, for in Massachusetts they are not found until June, and are apparently most abundant in the month of July.   They are eaten and relished by many people who have the greatest dread of what they know to be fungi.   This form has been called by Peck, *Exobasidium Azaleæ,* in the "Bulletin of the Buffalo Society of Natural Sciences," Vol. I. No. 2, p. 63.   Fuckel, in " Symbolæ Mycologicæ," Appendix II. p. 8, remarks that, under the name of " saft-apfel," the galls produced by *Exobasidium Vaccinii, var. Rhododendri,* are eaten in Switzerland.   The most eccentric form of *Exobasidium,* described by Peck as *E. Andromedæ* (l. c.), is found on *Andromeda ligustrina,* the leaves of which swell to an enormous size, often eight or ten inches in length, and finally become hollow and sac-shaped.   This form is not apparently known in Europe ; and, if any of our forms are to be considered distinct species, this is the one. Fuckel finally concluded that his *Exobasidium Rhododendri* was only a variety of *E. Vaccinii ;* and that view is now adopted by the best mycologists.   As far as the fungus is concerned, we can see no specific distinction in the forms found in this country ; and, although the distortions vary in different cases, we must think that there is only one species of fungus.   Of *Exobasidium Cassandræ,* Pk., which grows on *Cassandra calyculata,* we have seen only sterile specimens received from Hon. G. W. Clinton.

PERISPORIACEÆ. — An interesting fungus occurs frequently on the catkins of the alder near Boston, which was described as *Erysiphella aggregata* by Peck, in the 28th Report of the " Botanist of New York State."   We cannot, however, agree with Mr. Peck, that the species should be separated from *Erysiphe* on the ground that it is destitute of appendages.   On the contrary, the appendages are very numerous, and we do not understand why it is not a perfectly good *Erysiphe.*   It certainly is closely related to *Erysiphe Graminis,* both in the character of the mycelium, the light-colored appendages, in the half-immersed perithecia, and in the asci and spores.

We have received from Dr. J. H. Mellichamp of Bluffton, S. C., numerous specimens of *Meliola amphitricha,* which seems to be as common and to inhabit as many different plants as *Phyllactinia guttula* in our region.   The *mycelium* of this species was distributed by Curtis under the name of *Glenospora melioides.*

HELVELLACEÆ. — We have several times found on *Abies balsamea* a fungus which has given us a great deal of trouble to determine. It was evidently the stylosporous condition of a *Cenangium*. The fungus is of a silvery-gray color, the disk is depressed and surrounded by a thin margin, and the surface is generally dotted with minute white spots. A section shows a number of cavities lined with stylospores, which are bluntly crescent-shaped, at first containing oil globules, and afterwards divided by septa into three or four divisions. The stylospores are white and readily escape from the cavities through the somewhat elongated necks and accumulate in heaps around the mouths of the cavities, forming the white spots visible to the naked eye. The name of *Fusisporium Berenice*, B. & C., is given to the white spots in Grevillea, June, 1875, p. 147, and the name of *Cenangium pythium*, B. & C., is given to the whole fungus in Grevillea, September, 1875, p. 4. The name of sporidia, however, can hardly be applied to the spores in "Sprague, No. 5827," in which, although the spores answer perfectly to the description given, yet they are not contained in asci, but are properly stylospores. In the "Bulletin of the Buffalo Society of Natural Sciences," Vol. III. No. 1, p. 25, *Cenangium pythium*, Fr., is mentioned by Cooke as occurring in Salem (S.), Car. (S.), and N. Eng. (Sprague). The specimens of Sprague, in Herb. Sprague and Herb. Curtis, belong to the species described in Grevillea (l. c.) as *C. pythium*, of Berkeley and Curtis, which is quite different from *C. pythium* of Fries. The reference Salem (S.) and Car. (S.) probably relates to the species mentioned by Schweinitz, in "Syn. Fung. Am. Bor.," No. 1993, and quoted by Curtis, in his "Catalogue of the Plants of North Carolina," p. 137, which is entirely different from Sprague's plant, and which, although a *Triblidium*, does not seem to correspond to the specimens of *C. pythium*, Fr., in our possession. We have received from Professor Bessey an interesting fungus growing on *Potentilla Norvegica*, which corresponds closely to the species figured by Albertini and Schweinitz, in "Consp. Fung.," Pl. IV. fig. 6, as *Xyloma herbarum*, a species referred by some writers to *Phacidium repandum*, Fr. The species, however, does not agree with the fungus of that name on species of *Galium* distributed by Desmazières.

PYRENOMYCETES. — An interesting fungus was found by Mr. Halsted on an undetermined species of grass growing near the Bussey Institution, in the month of July. It first showed itself in the form of

a grayish-colored stroma, which afterwards developed in spots into dark-colored masses, in which finally perithecia were formed and asci containing very long and filiform spores. The fungus was described in " Grevillea," March, 1876, under the name of *Dothidea vorax*, B. & C. Two forms are mentioned by Berkeley, to which the names of *D. pilulæformis* and *D. atramentaria* were given. Our fungus corresponds to the former represented in Herb. Curtis by No. 1809, Santee Canal, S. C., collected by H. W. Ravenel. The same species was described by Peck, in the 27th Report of the " Botanist of the State of New York," p. 108, under the name of *Epichloe Hypoxylon.* A question of priority may arise, because, although the Report was for the year 1873, and bears the date of December, 1875, it was not given to the public until the latter part of 1876, if we are to consult the date at which it was sent to the publishers of the "Torrey Bulletin." To go back of that date would be to open the question of manuscript names, which would result in the adoption of the name of Berkeley and Curtis, as the fungus was first examined and named by them in about 1854. As to whether the fungus should be called an *Epichloe* or a *Dothidea*, we do not care to express a decided opinion. The genus *Epichloe* depends for its existence more upon the peculiar habitat of the species included in it than upon any distinct anatomical characters. The present species if considered an *Epichloe*, would seem, however, to weaken the claims of the genus to a position apart from *Dothidea*, in which *Epichloe typhina* has been placed by some writers. We should be inclined to take what some would call a backward step, and call the fungus simply *Sphæria vorax.*

In the 28th Report of the " Botanist of New York State," bearing the date of 1876, Peck refers to *Epichloe typhina*, found at Oneida by Warne, and says that he does not know that the plant has been before detected in this country. It was, however, found by Schweinitz on *Muhlenbergia erecta*, and mentioned by him in the " Syn. Fung. Car. Sup.," No. 65, in 1822, and again by Curtis (l. c. p. 151). It was collected in South Carolina by Ravenel, and referred to by Berkeley in " Grevillea," September, 1875, and it has recently been sent by Professor Ç. V. Riley from Missouri.

The ergots or sclerotioid forms of different species of *Claviceps* are common near Boston. Besides the form on rye, we have found it on

* *Vid.* "Bulletin of Torrey Club," January, 1877.

Festuca nutans, *Phalaris arundinacea*, *Poa pratensis*, and *Spartina stricta*. Cultures have been made of the ergots on the above-named grasses, and, although they have begun to grow, it is not yet possible to say whether they all belong to *Claviceps purpurea*. The ergots on *Festuca*, *Phalaris*, and *Poa*, were all small and pointed. The form on *Spartina* was found in abundance along the Charles River, in Cambridge, during the month of October, and was exceedingly beautiful. In some cases, nearly all the flowers were affected; and there were as many as forty or fifty ergots on a stalk, all from one to two inches long and regularly recurved.

IMPERFECT FORMS. — During the winter of 1876–77, we received specimens of onion bulbs, which were more or less injured by the smut, from Green's Farms, Ct. On the outer scales of the bulbs, the smut was mixed with *Aspergillus niger*, Van Tieghem. The *Aspergillus* was identical with European specimens. Another small and delicate species of *Aspergillus* found on an excrescence on blackberry stems, answers tolerably well to the descriptions of *A. niveus*, Mich.; but its conidia are not produced on basal processes, which have several sterigmata, as is said to be the case in that species. We have found a *Pestalozzia*, which seems to be identical with *P. truncatula*, Fuckel, common on the cones of Norway spruce at Newton. We have received from Mr. W. C. Stevenson, Jr., the same fungus on spruce cones from Westchester Co., Pa., to which the name of *P. Stevensonii* has been given by Mr. Peck, in the "Bulletin of the Torrey Club," Vol. VI. No. 26.

NOTE. — We are indebted to Mr. M. C. Cooke for calling our attention to the fact that there is no description of *Hendersonia Curtisii*, Berk., *H. nobilis*, B. & C., nor *H. pubens*, B. & C. Of the first-named species, there is but one specimen in Herb. Curtis; "No. 2102, fol. mort. Narcissi? Society Hill, S. C." The spores which we have examined are hyaline and undivided, and too young to allow one to say whether the species is a *Hendersonia* or not. There is a sketch, however, attached to the specimen, showing a spore with one septum and another with two. *H. nobilis*, B. & C., is also represented by a single specimen; "No. 5027, ad lign. denud. Caryæ, April, 1855, Society Hill, S. C." The spores are oval, .009–.012 mm. by .02–.024 mm., dark colored, usually uniseptate, and usually but not always constricted at the septum. We have only in one or two instances seen two septa in the spores of this species, and do not understand why it should not be called a *Diplodia*. It must not be forgotten that there is a *Hendersonia nobilis*, Dur. & Mont. Flore d'Algérie.

With regard to *Hendersonia pubens*, B. & C., mentioned in Curtis's "List of North Carolina Plants," the literature is very complicated. The specimen

quoted by Curtis is marked "(205) Ram. mort. ignot. (145), Ram. mort. Robiniæ Pseud. March, Hillsborough, N. C." The spores .005½–.007¼ m m., by .015–.025, dark-colored, with from three to seven septa, and not unfrequently vertical septa as well. This is the same as *Sphæria pubens*, Schw. of " Syn. Fung. Am. Bor. No. 1426," as was recognized by Curtis, and as can be easily seen on examining the original specimen of *S. pubens*, Schw. Precisely the same fungus exists in the Curtis Herbarium, under the name of *Hendersonia Sartwellii*, B. & C. on *Atlanthus*, No. 1857. In " Grevillea," September, 1874, the name of *Hendersonia subfenestrata*, B. & C., is given to Nos. 145 and 205, and No. 1857 is referred to *H. Berkeleiana*, Lev. It will be necessary to unite 205, 145, and 1857, of Herb. Curtis, and, recognizing the existence of *Sphæria pubens*, Schw.; call it *Hendersonia pubens* (Schw.), B. & C., or, on Berkeley's authority, suppress all names but *H. Berkeleyana*, Lev.

Schrœter in Hedwigia Vol. XIV., p. 171., asks whether *Uredo chelidonii* Schw. may not be related to the fungus described by Magnus as *Cæoma Chelidonii*. There is a Schweinitzian specimen marked *U. Chelidonii* in Herb. Curtis, which on examination, however, proves to be a *Puccinia*.

No. 21. — *Preface to Part IV., Volume 2, of the Bussey Bulletin.*

AT the beginning of the first volume of the Bulletin will be found an account of the origin and objects of the Bussey Institution, together with a statement of the resources which were at that time available for carrying on scientific investigations. In consequence of the great fire in Boston in 1872, and of the commercial crisis of 1873, the income of the Institution was so much reduced in the course of a few years that researches became impracticable, and all the remaining resources of the Institution had to be applied directly to purposes of teaching. It has been and is the intention of the government of the University, and of the teachers specially appointed for the Bussey Institution, to make it a thorough and genuine School of Agriculture and Horticulture. The whole available income from the Bussey Trust and from tuition fees is therefore expended each year for the maintenance of the buildings and for instruction.

The present number of the Bulletin, published at the cost of a friend of the Institution, contains papers descriptive of experiments that were made several years ago, before the closing of the laboratory of research and the experimental plant-house, together with others relating to subjects which could be studied with very simple appliances. The dates attached to the several articles denote the times at which they were written.

The peculiar pecuniary difficulties of the Bussey Institution, as compared with the other departments of the University, result from the fact that — in accordance with directions given by Mr. Bussey in his will — the "Bussey Trust Fund" is specially invested in real estate, consisting of stores in the best business quarter of Boston. It happened that several of these stores were burned in 1872, and that for rebuilding them there was expended, besides the insurance money, not only the whole of the Bussey interest in the general investments of the University ($80,000), but also $40,000 borrowed at interest from the University Treasury, the Corporation not deeming it proper to give to the Bussey Trust any share of the proceeds of the public subscription which · was raised for the purpose of making good the losses which the University had suffered through the fire. In 1876 there was a serious

fall in the rentable value of the Bussey stores, as of all similar property in Boston, and from this decline there has been only a slight recovery.

The following table clearly exhibits the difficulties under which the Institution has maintained, thanks to the devotion and determination of its teachers, its full course of instruction.

Income of the Institution from the Bussey Trust.

1875–76	. . . . .	$17,155.92	1879–80	$3,505.30
1876–77	. . . . .	8,902.98	1880–81	3,551.52
1877–78	. . . . .	8,825.52	1881–82	4,685.06
1878–79	. . . . .	5,113.35	1882–83	5,223.48

Recent changes in the manner of conducting the Bussey Farm, and the establishment of a Veterinary Department in the University, have opened to students facilities which are in some respects better than those before offered.

July, 1884.

No. 22. — *On the Results of Fodder-Analyses of Leaves of the Yellow- or Curled-Dock (Rumex crispus), and of Sprouts of the common Milk-Weed (Asclepias Cornuti).* By F. H. STORER, Professor of Agricultural Chemistry.

In continuation of the work upon Weeds that are Used as Human Food, which was published in an earlier number of the Bulletin,* I have had analysis made of the common yellow dock of mowing fields, and of the familiar milk-weed or silk-weed (*Asclepias Cornuti*), both of which plants have been used as food not infrequently at one time and another in various parts of this country. That is to say, in the lack of spinach and asparagus, the weeds were boiled and eaten as greens by our country people, as they doubtless are still eaten in many localities where no pains are taken to cultivate better vegetables.

I have myself repeatedly heard one or the other of these practices spoken of in different parts of New England, and there is no lack of printed statements to the same effect. Thus in respect to dock, Cobbet says † : —

" I have frequently mentioned the leaves of this weed as being sold in the market of New York. . . . The dock (which is the wild rhubarb) puts forth its leaves very quickly after the dandelion; and hence it is that it is resorted to as greens in the spring. It is however a coarse green compared with the dandelion. However, it is better than no greens at all after five months of winter, which has left nothing green upon the face of the earth. . . . The dock-leaf is very wholesome, as is also that of the dandelion. They do not produce gripings as the greater part of the cabbage kind are apt to do."

So, too, Darlington, in his "American Weeds and Useful Plants," New York, 1859, remarks that the radical leaves of the curled dock are often used as a pot herb or early greens. And the U. S. Dispensatory of Wood & Bache, 1867, p. 719, under the head of *R. crispus* says : —

" The leaves of most of the species of dock are edible when young, and are occasionally used as spinage. They are somewhat laxative, and form an excellent diet in scorbutic cases."

There is, indeed, small cause for surprise that dock leaves should be used as food in view of the close botanical relationship

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* Bulletin of the Bussey Institution, **2.** 115.

† As quoted in the "New England Farmer," 1828, **6.** 251.

of the plant to such familiar esculents as rhubarb (*Rheum raponti-cum*)* and sorrel (*Rumex acetosa*). For statements of the importance of the latter as a vegetable proper, see Burr, F., "The Field and Garden Vegetables of America," Boston, 1863, pp. 304–309. According to Loudon, in his "Encyclopædia of Plants," p. 294 : "All domestic cattle eat this sorrel and most other species of the genus." And Sprengel† asserts that it affords a very healthy nourishment to all grass-eating animals. Sprengel‡ states furthermore that the common sheep-sorrel also (*R. acetosella*) is readily eaten by cattle, so long as the plants are young, and that it affords tolerably good nourishment for cows and sheep. The significance of sheep-sorrel as forage in this country has been insisted upon by a writer in the "New England Farmer" for 1859 and 1862 (vol. 11, p. 290, and vol. 14, p. 242). According to his testimony, a hay that has considerable value, and which is eagerly eaten by sheep and horses, may be obtained by cutting sorrel when it is green and succulent and before the seeds have scattered out. In order to cure the sorrel without loss, it should be mown in the early morning and raked into small bunches or cocks as soon as the dew has left it. It should be allowed to dry in these cocks with as little exposure to the sun as possible. According to the U. S. Dispensatory of Wood & Bache, 1867, p. 718, the leaves of sorrel quite lose their agreeable sour taste in drying.

It is to be remarked, however, that neither dock nor milk-weed

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* It is to be noted in this connection that statements are upon record to the effect that the leaves of rhubarb, as distinguished from the leaf-stalks, may sometimes be hurtful. One report of this kind will be found in the "New England Farmer" for 1845, **23.** 20, and in Taylor "On Poisons," Phila., 1859, p. 292, to the effect that a family of four persons, after eating very freely of the *leaves* of the domestic rhubarb or pie-plant, boiled and served as greens, were all of them shortly afterwards seized with severe vomiting. In one of these persons the attack was followed by gastritis; but the others recovered soon after the vomiting. Another instance is cited in the "Report of the U. S. Commissioner of Agriculture" for 1869, p. 418, in the following terms: "Mr. Passmore of Pennsylvania wrote that he prepared for market twenty-five bunches of common rhubarb by stripping the leaves from the stalks. These leaves were thrown to the hogs. The result was that five out of nine of the animals died, three were convalescent at the date of the letter, and the other was in a doubtful condition. Those that died gave every symptom of having been poisoned."

† Erdmann's "Journal tech. und œk. Chemie," 1830, **9.** 2.

‡ Ibid., 1829, **5.** 74, and 1831, **10.** 65.

are so well adapted for being made into hay as sorrel. They dry with extreme slowness, and the presence of such succulent plants in mowing fields must be objectionable on account of the liability of carrying lumps of them to the stack or mow in a half dried state, to the injury of the hay proper. Indeed, it is not at all impossible that beside mouldiness and the moderate " heating " which would be induced by moisture in the stack, the hay might sometimes even be set on fire by the undried leaves of certain weeds. A belief in the possibility of this result was long ago popularly current in some parts of England, as may be seen by referring to the heading " Fire-leaves " in the Dictionary of English Plant Names, published by the English Dialect Society. It appears that the name fire-leaves is applied by the common people to certain succulent leaves which, as they think, are liable to set ricks on fire. In Gloucestershire plantain leaves, and in Herefordshire those of Devil's bit (*Scabiosa succisa*) are called fire-leaves.* Perhaps the occasional presence of nitrates in such leaves may be one cause of their spontaneous combustion? On page 127 of volume II. of the Bussey Bulletin, I have mentioned a case that fell under my own observation, where purslane that had grown in a garden border was found to be highly charged with nitrates.† It is known that the leaves of many other kinds of succulent weeds which feed grossly may become charged with nitrates under favorable circumstances, as when grown on very rich land in warm weather.

The use of the young stalks of milk-weed as an article of food is mentioned in the "New England Farmer" for 1829, vol. 8, p. 61, and repeatedly in subsequent volumes. Thus, in 1835 (vol. 13, p. 373),‡ an article quoted from the "Baltimore Farmer" contains the following statements : —

" Milk-weed has long been used in Canada for culinary purposes as a substitute for asparagus. It is easily cultivated. . . . When the young shoots are four or five inches from the ground, they may be cut and served up in the manner of asparagus. . . . Parkinson received the plant from this country and cultivated it (in England)

* " Old Country and Farming Words," p. 18.

† I notice that Lemery is credited with a similar observation, made some time during the first half of the last century. The presence of nitrates in many different kinds of weeds was observed by several of the European chemists who so carefully studied the theory and practice of nitrification about the time of the American revolution.

‡ A good part of the same statement was repeated in the next volume of the " New England Farmer," 1835, **14.** 117.

in his botanical garden of rare plants as early as 1629. He called it Virginia Silk, and it was stated that the French Canadians were in the habit of eating the tender shoots as substitutes for asparagus."

So too, Loudon, in his "Encyclopædia of Plants," says that "the French in Canada eat the tender shoots of milk-weed in spring as we do asparagus."

In 1860 another writer in the "New England Farmer" (vol. 12, p. 350) commends the flavor of milk-weed greens, as being "Indeed excellent and but little inferior to that of green peas, which it nearly resembles." This writer gives the following directions for gathering the plants : —

"Gather them while the stalk is brittle, say from four to six inches high, break out the little bud [apparently because it is specially liable to harbor insects], and boil the stalk and leaves until soft and tender."

A writer in the "Genesee Farmer," in lamenting the spread of the weed in pastures, meadows, and the richest lands, expresses himself incidentally in the following terms * in regard to its edibility : —

"General Dearborn of Boston † recommended the culture of milk-weed as a substitute for asparagus, and the tops are sometimes used as greens, but there is no known use to which it can be applied which will justify the farmer in allowing it to grow on his land. In one instance where a very luxuriant patch of this plant was ploughed up, pigs were allowed to run upon the ground. They · ate the roots voraciously, and a number of them were poisoned and died in consequence. . . . An efficacious method of destroying the plant is to sprinkle salt on the full-grown leaves when wet, and turn a flock of sheep to them. The sheep will soon strip the stems of every leaf, and the bleeding of the plant, aided perhaps by the action of the salt, will ensure the destruction of the patch. No harm has ever resulted to the sheep so employed."

The specimens examined in this laboratory were collected in the spring of 1877 ; they were dried upon racks in the shade in an airy glass-house that contained no growing plants, and were stored in a loft in tight paper bags until analyzed in July of that year. It was noticeable that the plants dried with extreme slowness, and that they retained the last portions of moisture very forcibly. No estimations were made of the amount of moisture in the green

* As quoted in the "New England Farmer, 1837, **16**. 91."
† In the "Massachusetts Horticultural Register."

plants.   The analyses refer merely to the " hay " or air-dried plants.

I. CURLED OR YELLOW DOCK (*Rumex crispus*).   The specimen was collected May 21, 1877, upon the Plain-field of the Bussey Institution.   It consisted entirely of leaves in tufts or branches from one foot to a foot and a half in length.   No flower stalks or buds had yet appeared upon the plants.   Apple-trees were beginning to blossom in the vicinity at the time.   The following results were obtained on analysis : —

Curled Dock.	Air-dried.	Dried at 110° C.
Water	12.21	——
Ash (free from C & CO₂)	9.51	10.83
Albuminoids	22.28	25.38
Carbohydrates (including fat) . . .	44.33	50.50
Cellulose (free from ash)	11.67	13.29
	100.00	100.00
Dry organic matter	78.28	89.17
Fat (ether extract)	3.98	4.53
Nitrogen	3.53—3.60	4.06
Crude ash	11.08	12.62
Ratio of albuminoids to carbohydrates	1 : 2	1 : 2

II. MILK-WEED (*Asclepias Cornuti*).   Sprouts and shoots from four to twelve inches long were cut off just below the surface of the ground on the 23d and 28th of May, 1877, at times when apple-trees were in blossom and going out of blossom.   Although the shoots dried with extreme slowness, none of them blackened in drying excepting a single stalk, which was thrown away.   The dry stalks and the leaves attached to them were all ground to powder together for the analysis.   The following results were obtained : —

Milk-Weed Shoots.	Air-dried.	Dried at 110° C.
Water	14.91	——
Ash (free from C & CO₂)	8.15	9.58
Albuminoids	23.75	27.91
Carbohydrates (including fat) . . .	37.26	43.79
Cellulose (free from ash)	15.93	18.72
	100.00	100.00
Dry organic matter	76.94	90.42
Fat (ether extract)	5.98	7.08
Nitrogen	3.78—3.82	4.47
Crude ash	9.18	10.78
Ratio of albuminoids to carbohydrates	1 : 1.6	1 : 1.6

It appears from these analyses that both the milk-weed and the dock are highly nitrogenous plants when young, and that their composition compares favorably with that of the weeds previously studied (see page 128). They doubtless have considerable value as fodder, as would naturally be inferred from the fact of their having been used as human food.

I am indebted to my assistant, Mr. D. S. Lewis, for aid in this investigation.

January, 1878.

No. 23. — *Trials to Determine the Rates at which some Fertilizers may be Scattered by Hand.* By F. H. STORER, Professor of Agricultural Chemistry.

I HAVE several times been asked the question: "About how much of a given fertilizer would a man naturally throw from his hand in sowing an acre of land?" With the view of getting at least an approximate answer to this enquiry, I measured off a half-acre of level grass-land upon the Plain-field of the Bussey Institution, and marked its limits with numerous stakes; and in April, 1878, set a careful laborer the task of scattering fertilizers upon this half-acre, "as if he were sowing grain thickly." It should be said that the purpose of the trials was solely to determine the rate of the scattering, and that the fertilizers were chosen merely to this end. I made no estimate, even, of the increase in the crop of grass, which to all appearance was considerably more than doubled. A definite quantity of each of the fertilizers was weighed out at the beginning, and when the plot had been completely sown the unexpended residue of the fertilizer was weighed, and subtracted from the original weight, in order to find how much had been actually scattered. It was found that there had been scattered of —

	On the half acre.	[Or, on an acre.]
Nitrate of Soda	107 lbs.	214 lbs
Muriate of Potash	86½ "	173 "
Superphosphate of Lime	86½ "	173 "
Blood, Bone, and Meat-Dust fertilizer	62 "	124 "

The substance sold under the name of blood, bone, and meat dust, is the dried refuse of slaughter-houses. It is a light, soft, dry powder, so fine that, with the exception of some fragments of teeth, the whole of it passes readily through the meshes of a $\frac{1}{16}$-inch sieve. A struck bushel of it weighed 50 lbs.

The superphosphate was in the state of fine dry powder. A struck bushel of it weighed 68 lbs.

Both the muriate of potash and the nitrate of soda had been beaten on a board floor with the flat of a spade. The muriate was in the state of a fine soft powder, the whole of it passed readily through $\frac{1}{8}$-inch meshes, and most of it through meshes of $\frac{1}{16}$-inch. A struck bushel of it weighed 69 lbs. The nitrate of soda was still rather coarse. A few fragments were still as large as large peas or maize, and there were many of the size of small

peas. Nevertheless, a large proportion of the powder passed through meshes of $\frac{1}{8}$-inch. A struck bushel of it weighed 88 ℔s.

The Irishman employed for the foregoing trials was an old, experienced, and careful farm-laborer, accustomed to sow grain upon small fields. He had often been employed by myself to scatter fertilizers at will upon grass-land, in previous years. In the present instance he carried the supply of fertilizer in a wooden water-pail hanging upon his arm. It is to be noted that this laborer worked without the least bias in favor of scattering any particular quantity of the fertilizers. In fact, he had not the slightest idea of the drift of the operations upon which he was engaged. He knew only that I wished to have the materials sown evenly and truly, and he did his best to accomplish this result.

In order to determine how much the rates of scattering would differ from the foregoing results, in case the materials were sown by a man of different mould from the old-country man above described, I appealed to one of the students of the Bussey Institution, an exceptionally intelligent American of one and twenty years, whose height exceeded six feet by more than as many inches as the Irishman's fell short of it, and he was good enough to carry out my wishes. He had watched the slow and careful operations of the laborer with no sympathy, and proceeded to do the work in a very different way. He carried the fertilizer in a seed-bag slung upon his shoulder, and marched over the field at a much more rapid pace than that of his predecessor. He had no knowledge as to the actual weights of the materials sown, either by himself or by the workman, yet it appeared on summing up his work that he had strewn nitrate of soda at the rate of 194 ℔s. to the acre, and muriate of potash at the rate of 116 ℔s. It should be said that this young man, though reared upon a farm and accustomed to labor, had had little or no experience as a sower. He had on one occasion strewn land-plaster upon his father's farm, but had never undertaken to sow anything that requires care. He himself clearly recognized the fact that he could not throw the materials so evenly as the skilled laborer. In a word, the two operators employed in these trials were as unlike as they well could be, and I deemed it remarkable that the results obtained by the young man were not more different than they were from those of the old laborer.

I am inclined to accept the latter's work as normal, and to regard the figures given in the table as useful indicationsof what

would actually happen in field practice in case the specified fertilizers were sown by hand.

It will be noticed that the figures of the table agree very well with certain common rules or statements, current in agricultural literature, concerning the amounts of saline manures proper to be applied in practice ; and it may well be true that some of these rules were originally based upon observations of the amounts of material that a man could conveniently scatter.

No. 24. — *Experiments on feeding Mice with Painter's-putty and with other mixtures of Pigments and Oil.* By F. H. STORER, Professor of Agricultural Chemistry.

I HAVE often speculated as to the cause of the white color of the dung of mice, as seen in buildings where the animals have little or no access to their usual forms of food. Such dung is particularly noticeable in and about churches, lecture halls and school-houses, especially in the cellars and lumber rooms of such buildings ; and it may often be seen in greenhouses also and in unoccupied dwelling houses.

At one time, on the occasion of finding large quantities of the white dung under circumstances which suggested that the animals might have eaten chalk from the trough of a school blackboard, I was led to infer that starving mice may perhaps sometimes eat mere chalk as a means of distending their stomachs and allaying the cravings of hunger, like the savages in various parts of the world, who, as travellers tell us, occasionally resort to "dirt-eating." It would appear, however, that this supposition is not correct, at least not for the generality of cases, and that the real source of the white mouse-dung is common painter's-putty, which is so largely used in the construction of houses, not only for cementing the glass of windows, but for covering the heads of sunken nails in boards that are to be oiled or painted, as well as for stopping all manner of cracks and holes in wood-work. This putty is prepared by mixing ground chalk (the so-called *whiting*) with oil, either linseed-oil or that from the fish known as menhaden or pogy, — and it is the oil in the putty which attracts the mice and serves them as food.

I was led to the knowledge of these facts by the following accidental observations. Having had occasion to employ some workmen in a dark cellar at the Bussey Institution, I gave them a couple of small tin lamps charged with lard oil, each lamp being provided with a plain unwoven wick, composed of coarse, loosely-spun cotton threads, which fitted rather tightly into the tube or socket at the top of the lamp. At the close of the day's work the lamps were extinguished and left upon a bench in the cellar. But next morning, on trying to relight them, it was found that the wicks were no longer in the sockets, but that around each lamp

there hung a regular festoon of dry cotton threads. During the night the mice, with which the cellar was infested, had methodically and completely dragged out from the sockets of the lamps each particular strand or fibre of which the wicks were composed and had eaten all the oil which was attached to the wicks. The animals had evidently pulled up the strands one by one and little by little, and had sucked off the oil from the cotton as they went along; the result being that the threads were free from oil and that they hung around the lamps in festoons the beauty and symmetry of which were little short of the miraculous.*

Some months later I employed a glazier to set several panes of glass in sashes that were standing in the garret of the same building, and was not a little surprised to find no putty upon the glass when these sashes were brought down from the attic a few weeks afterward. The glazier assured me that he had faithfully puttied the glass and that the putty had undoubtedly been eaten off by mice. I then learned, what I have repeatedly verified by further conversation, that painters and glaziers are continually annoyed by the depredations of mice, these animals being very fond of putty and apt to feed upon it at inopportune times. Several painters have told me, furthermore, that they are unable to check these depredations by mixing white-lead or red-lead with the putty, since they find that the mice eat the mixed putty apparently without harm to themselves.

In view of the physiological interest of these statements, I determined to try a few definite experiments upon the consumption of putty by mice; but I had hardly begun the enquiry when it occurred to me that curiously enough the question of putty-eating must have a by no means unimportant bearing upon the health of the community wherever water-closets are maintained in houses, at least when the closets are fitted in the manner usual in this vicinity. For, as it happens, the leaden " trap" or water-seal, — beneath the porcelain-bowl of the water-closet, — which is supposed to prevent the foul gases from the sewer or cess-pool from entering our houses, is fastened into the iron soil-pipe by means of a " putty-joint." That is to say, the leaden trap is cemented into a flange or socket of the iron pipe by means of painter's-putty, and if perchance this

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* Sir J. G. Wilkinson, in his " Manners and Customs of the Ancient Egyptians," London, 1878, **2.** 91, *note*, says : " In the churches of the Copts, the rope of the lamp is sometimes passed through an ostrich egg-shell in order to prevent rats coming down and drinking the oil."

putty should be eaten by mice an opening would be made beyond the trap for the free passage of sewer gas into the house. On proceeding to make enquiries of plumbers as to whether they had ever noticed the occurrence of this event, I found that they are familiar with it. One master-workman assured me that in fitting up the water-closets of new houses the mice had sometimes destroyed the putty-joints of his work at the top or bottom of the house before he had finished cementing the joints at the other extremity of the house. Like the painters, the plumbers assured me that the admixture of white-lead or red-lead with the putty does not prevent mice from eating it. They hold that the best way of protecting their putty-joints is by binding a strip of thin sheet metal around the finished joints in such wise that the mice cannot get at the putty.

In the following experiments, which were continued during eight or nine months, the mice were kept in a small box 9 × 12 inches, placed in a comfortable room. Commonly, there were three of the animals in the box, new ones being introduced occasionally to replace those that perished. They were provided with cotton-wool for a nest, and with as much water as they wished. For several days after their capture they were given more oats than they could eat, but as soon as they had become wonted to the cage, the supply of oats was cut down to a quantity no larger than was sufficient to maintain the animals in good case,* and balls of putty made of whiting and raw linseed-oil † were daily placed in the cage. It was found immediately that the mice ate the putty freely and in quantities which must be regarded as very large when the small size of the animals is considered. For example, three mice ate during terms of seven or eight days as many as 10 or 12 balls of putty daily beside their allowance of oats. The putty balls were just large enough to pass without touching through an auger-hole three-eights of an inch in diameter. Meanwhile the dung of the animals became perfectly white and of very large size, often more than twice as large as the ordinary dung of mice.

At one time, in the month of February, after the mice had been fed upon putty, as above, for ten days, a special quantitative trial was made for the purpose of ascertaining the weight of dry whiting

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* Each mouse got 25 kernels of oats, amounting to 0.835 grammes, on the average, per day.

† Probably adulterated with fish-oil, as is the custom in this vicinity.

that was consumed; and it appeared that beside their $3\frac{1}{2}$ grammes of oats, the three mice ate daily, during three consecutive days, 12 balls of putty of the size above mentioned, weighing all told 20 grammes, and containing 16.7 grms. of whiting and 3.3 grms. of oil. That is to say, each of the mice swallowed every day and discharged again as dung more than $5\frac{1}{2}$ grms. of dry whiting. But since these particular mice weighed little more than fifteen grammes apiece, it appears that the quantity of inert earth (whiting) that passed through them daily amounted to more than one third the weight of the animals. It is as if more than 50 lbs. of dry chalk were to pass daily through a man of 150 lbs. weight.

It should be said that I made no attempt to determine how long this large consumption of whiting could be kept up. Ten or twelve balls of putty a day appeared to be very nearly the limit of the amount which the three mice were willing to consume, but it seemed probable that this limited rate of consumption could be maintained for a long time, if not for an indefinite period. Several attempts were made in January to induce the mice to eat fifteen balls instead of twelve, but they invariably left one or two of the balls uneaten in this case.

The foregoing results afford a striking illustration of the power of the animals to extract very small amounts of nutritive matters from a great mass of inert material. For the sake of the $3\frac{1}{2}$ grms. of oil, with which it was admixed, the mice swallowed more than five times this amount of whiting.*

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* A somewhat analogous instance is that of the bones eaten by dogs and other carniverous animals. About one third part of the bone may be regarded as organic matter (ossein), but from the immobility of the ossein and its inaccessible position, enclosed as it is by the bone-earth, it seems improbable that anything like the whole of that contained in the bones is digested.

In some wild districts, sheep and cattle are accustomed to eat very considerable quantities of certain clayey and sandy earths for the sake of a very small proportion of common salt which these earths contain, and it has been noticed that the animals appear none the worse for this habit of dirt-eating. Compare Muir, in "Chemical News" **36**. 202, and Liebig, in his "Familiar Letters on Chemistry," London. 1851, p. 414, *note*. — citing the Mogling'sche "Annalen," 1847. **2.** 29.

So, too, William Bartram (in his "Travels through North and South Carolina, Georgia, Florida, &c.," London, 1792, page 39), describing a Buffalo Lick some 80 miles from Augusta, Georgia, on the ridge which separates the waters of the Savannah River from those of the Altamaha, says: "The place called the lick is nearly level and contains three or four acres. The earth, from the superficies to an unknown depth, is an almost white or cinerous-

To prove that the mice ate the putty for the sake of the oil contained in it, special experiments were made in which lumps of solid chalk and balls of whiting made up with water, and of gypsum also, were offered to the mice, both at times previous and subsequent to those when the animals had been fed with putty. But none of these balls of chalk, whiting, or gypsum, free from oil, were ever eaten, no matter whether they were dry or moistened with water. At the most, marks of the animals' teeth could sometimes be detected on the whiting balls, but this was after the mice had become accustomed to eat putty and when they expected to receive a daily allowance of this substance. Sometimes the whiting and water balls, which were of course very friable, were found broken in pieces on the floor of the cage ; but on collecting and weighing the fragments, the differences between their weights and the weights of the original balls was so small, that there was no reason to attribute the loss to any other source than mere mechanical waste, due to the adhering of some particles to the floor of the cage or to the cotton of the nest. Meanwhile the animals always began to discharge dark-colored dung on the third day after they had ceased to receive any putty.

The great bulk and enormous quantity of dung discharged under the conditions above described, illustrates very emphatically the purgative or rather the evacuative power of coarse, indigestible foods. It recalls the remark of Liebig [*] that the boundaries of those German provinces in which the bran-bread, called pumpernickel, is used may be traced by the remarkable size of the undigested remains of the food of the inhabitants which wayfarers leave behind the walls and hedges.

When the mice were eating putty freely, each separate piece or cylinder of their dung commonly measured a centimeter in length, — i. e. ten millimeters or nearly four-tenths of an inch, — and from $2\frac{1}{2}$ to $3\frac{1}{2}$ millimetres in thickness. Several cylinders were noticed that measured 12 mm. in length and $3\frac{1}{2}$ mm. in thickness

colored, tenacious, fattish clay, which all kinds of cattle lick into great caves, pursuing the delicious vein. It is the common opinion of the inhabitants that this clay is impregnated with saline vapors, arising from fossil salts deep in the earth ; but I could discover nothing saline in its taste, but I imagined an insipid sweetness. Horned cattle, horses, and deer are inordinately fond of it, *insomuch that their excrement, which almost totally covers the earth to some distance round this place, appears to be perfect clay ;* which, when dried by the sun and air, is almost as hard as brick."

[*] " Familiar Letters on Chemistry," London, 1851, p. 449.

at the broadest point. Twenty-five of these cylinders taken together weighed 1.65 grm. Whereas, on examining a quantity of normal. dark-colored mouse-dung taken from a cellar-shelf, — as well as that voided by the mice when first caught, — it appeared that such cylinders were usually about 6 mm. long, though sometimes no more than 3 mm., and about 2 mm. thick. One hundred of these old dry cylinders weighed 0.87 grm.

The contrast between the dung voided by the mice when they were fed with putty and directly afterward, at the time when balls made from whiting and water were offered them, was very striking. During the latter period the cylinders were only 3 or 4 mm. long and about $1\frac{1}{2}$ mm. thick ; and 25 of these little cylinders weighed only 0.16 grm., which is no more than the weight of $2\frac{1}{2}$ of the great cylinders voided at the time of the putty ration.

But the most surprising point in connection with the white dung is the small amount of oil that has been left in it. The dung of the putty-fed mice was friable and crumbly. When pressed with the blade of a knife it seemed to be no more plastic than pure whiting to which no oil had ever been added ; and on extracting the dung with ether it appeared that it contained no oil, or as good as none. For the sake of comparison two grammes of the white dung were leached with ether in one tube, while two-tenths of a gramme of the original putty were leached in precisely the same way in another tube. The $\frac{2}{10}$ grm. of putty yielded much oil, but the 2 grms. of dung gave only some small traces of what appeared to be biliary matter rather than oil.

It is interesting to compare this experiment with the observation of Gustav Meyer [*] in his experiments upon the digestibility of coarse bread, since it shows that the tendency of indigestible matter to pass rapidly through the intestinal canal may not be sufficiently marked in all cases to prevent the digestion of a substance possessing the chemical properties and the mobility of oil ; although, as Meyer has shown, the inert portions of coarse bread work very decidedly to prevent the digestion of some of the constituents of that kind of food, both by causing rapid evacuation of the intestines and by enveloping the digestible matters.[†]

[*] " Zeitschrift für Biologie," 1871, **7.** pp. 28, 48.

[†] Since the above was written, the experiments of Rubner (" Zeitschrift für Biologie," 1879, **15.** pp. 115, 188) have shown that, as a general rule, fat is pretty thoroughly absorbed from the intestines of men, even when it has been eaten at the same time with some tolerably bulky foods.

It was noticed in one or two instances that old putty which had been left in the air long enough to become rather dry and hard was less readily eaten by the mice than fresh putty that had just been prepared. Doubtless there is a point when putty in drying becomes so hard and firm, — *i. e.* when the oil it contained has undergone such complete chemical change, — that mice will no longer eat any of it. On this supposition it is easy to explain the fact, well known to builders, that mice are particularly liable to infest new buildings, at least in cities, for so long as the fresh putty of the woodwork continues to be edible the animals will have comparatively little difficulty in procuring a supply of food. There can hardly be any doubt that in such situations, in the lack of other eatables, the mice must often be compelled to supplement the oil ration with such animal food as they may be able to find in the shape of insects, larvæ, and worms. It is not unlikely indeed that, by destroying such pests, the mice may occasionally do some small good to the householder. The case is perhaps akin to that of the cosmopolitan house-sparrow — in some sort a flying mouse — who amid numberless acts of harm and annoyance, does occasionally perform one which suggests some slight justification for his existence, — to speak in the economic, utilitarian sense.

After the mice of my experiments had become accustomed to eat large quantities of ordinary putty, as above described, several other mixtures of pigments and oil were offered them, as will appear from the following statements : —

Red Ochre. A quantity of pure red oxide of iron (rouge) in a very finely divided state, was made into balls with raw linseed oil, and 11.1 grms. of the mixture * were placed in the cage. In the course of the first twenty-four hours the three mice ate 1.3 grms. of it. Their dung meanwhile became red instead of white, and much less bulky than it had been when putty was eaten. But on repeating the same dose of the red oxide on the following day, the mice would not eat any of it. The balls of red ochre being then removed and 12 balls of ordinary whiting-putty put in their place, all of them were eaten in a short time. Five hours after this substitution of whiting for red ochre it was noticed that an abundance of the large white dung had already collected in the cage.

It is not easy to explain the refusal of the mice to eat the mixture of red ochre and oil, since the insoluble ochre can hardly have

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* Containing 8.3 grms. of the oxide and 2.8 grms. of oil.

had any unpleasant taste, and since the oxide was in the condition of a very fine smooth powder. Inasmuch as the first mixture of ochre and oil was sticky and the surface of the balls was unpleasantly oily, or moist, as it were, it was thought that this circumstance might possibly have repelled the animals, but on preparing balls of ordinary putty that were similarly sticky and oily, they were readily eaten by the mice.

In order to determine whether it might not perhaps be true that the mice refused the ochre because of its being really hurtful to them, they were fed with putty made of mixtures of red ochre and whiting, which they ate tolerably readily though less freely than pure whiting-putty. For example, three mice ate 4 balls per day of putty prepared from a mixture of $\frac{1}{4}$ red ochre and $\frac{3}{4}$ whiting. Next day they ate 4 balls made from a mixture of $\frac{1}{2}$ red ochre and $\frac{1}{2}$ whiting, their dung being all the while of a bright red color, but they subsequently refused putty made from a mixture of $\frac{3}{4}$ red ochre and $\frac{1}{4}$ whiting, that is to say, they ate hardly any of it.

As will be seen further on, under carbonate of baryta, it is possible that the whiting protected the ochre from being acted upon by the gastric juice of the animals. That is to say, it is not altogether unlikely that the animals were made uncomfortable by such action in the case of the plain ochre, or that the ochre was unacted upon when mixed with a great excess of the more soluble whiting.

Yellow Ochre was hardly any more acceptable to the mice than red ochre. At first, when offered to them merely admixed with oil, they refused to eat it; but when mixed with whiting and oil they ate it rather readily. Thus, three mice ate 6 balls made from a mixture of $\frac{1}{4}$ yellow ochre and $\frac{3}{4}$ whiting, in the course of one day; 5 balls made from a mixture of $\frac{1}{2}$ yellow ochre and $\frac{1}{2}$ whiting in the course of the next day, and 4 balls of the same the day after. On the day following they ate 5 balls made from a mixture of 3 parts yellow ochre and one part whiting, out of 6 balls that were offered them. Finally they were given a number of balls made from yellow ochre alone (plus oil, of course) without any whiting, and they ate two of the balls during the first day and nearly three on the second day. The dung was of a clear yellow color during the continuance of these trials, but not of the enormous size which was so noticeable when whiting alone was used. It was remarkable how soon this yellow dung began to appear

after the mixtures which contained yellow ochre had been placed in the cage.

Gypsum and Plaster of Paris.   Mixtures of linseed oil and powdered gypsum were eaten rather freely, though somewhat less readily than ordinary whiting-putty, apparently because the powdered gypsum was less fine and smooth.   Six or eight balls of the mixture of gypsum * and oil were repeatedly eaten in the course of one day, and sometimes as many as ten balls were consumed. The dung meanwhile was of large size and white color, closely resembling that from ordinary putty.   Mixtures of plaster of Paris and oil were less acceptable.   After the three mice had become accustomed to the gypsum and oil they were given 9 balls ($= 12.4$ grms.) of a mixture of plaster of Paris (72.5 per cent) and oil (27.5 per cent) and they ate all but 3.5 grms. of it in the course of the day.   Next day the same quantity of the plaster mixture was given them and they ate nearly the whole of it ; but when a similar quantity was offered on the third day, the animals ate hardly any of it, though there was no evidence, other than this refusal, that they had suffered any inconvenience from what they had eaten previously.

Sulphate of Baryta was eaten readily in a single trial, and it appeared not to do the mice any harm.   The sample of sulphate employed was a pure precipitated article in the form of a very fine and smooth powder.   It passed from the animals as large white dung, like the whiting and the gypsum and plaster.

Silica.   Mixtures of pure precipitated dry powdery silica † and oil were eaten, though rather sparingly.   Three and four balls per day were eaten in several instances, but never so many as six balls.   The dung passed by the animals during the silica trials was much less decidedly white than that from the whiting and the sulphates.   It had a yellowish tint, apparently due to its state of aggregation.   Unlike the whiting-dung, it did not dissolve with effervescence when thrown into muriatic acid.

Clay.   Mixtures of oil and clay of good quality ("china clay") were not eaten when first offered to the mice.   Marks of the teeth of the animals were seen upon the balls, it is true, but no appreci-

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* Prepared by mixing plaster of Paris with water enough to make it "set" and powdering the mass after it had been dried at 212° F.

† Obtained incidentally in the analysis of silicates.

able quantity of the mixture was consumed. But considerable quantities of mixtures of clay and whiting were eaten, as will appear below. The first trial of such mixtures was made with 6 balls that contained, beside oil, 1 part of clay to 3 parts of whiting, and 4 of the balls were eaten. On repeating the trial next day with 3 fresh balls of the mixture all of them were eaten. Next day 6 balls made from equal parts by weight of clay and whiting were offered and 4 of them were eaten, and on the day following 4 fresh balls of the same mixture were eaten well-nigh completely. Four balls were then given made from $\frac{2}{3}$ clay and $\frac{1}{3}$ whiting, and 3 of them were eaten in the course of the day. Finally, putty made from clay alone was again offered, and it remained practically uneaten, as at first; though one of the balls was much broken, and tooth-marks were visible on several of the balls. The dung produced during the trials with clay was grayish-white and in much shorter cylinders than that resulting from whiting alone, as if there were greater difficulty in its passing through the animals.

*Carbonate of Baryta.** Three mice which had been fed for several weeks with putty were given some pure, soft (precipitated) carbonate of baryta made up into balls with oil. Next morning two of the mice were found dead, though only a small quantity of the barium compound had been eaten from one of the balls. The rest of the material was immediately removed from the cage and the other mouse was fed upon oats alone until it was plain that he

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* Carbonate of baryta was employed many years ago in England as a rat poison; and it would doubtless be of convenient use in some cases, such, for example, as the preventing of mice from girdling trees. But, as will be seen in the text, the barium compound needs to be pure in order to be efficacious.

Since this note was written, Professor Crampe of the Agricultural School at Proskau, in Silesia, has published the results of a series of experiments which were made by him to test the comparative activity of the various poisons most commonly employed for destroying rats and mice. He finds that the most effective of all is precipitated carbonate of baryta mixed to a thick paste with three times its weight of barley meal, and with water, and rolled into little pills.

Crampe found that while neither fowls nor pigeons ate this paste, rabbits did eat it and were poisoned by it. Hence it may possibly be true that in some cases the mixture of carbonate of barium and oil, such as was used in my experiments, may be exhibited to better advantage than Professor Crampe's paste. The latter is probably of more general applicability than the putty, but perhaps rather less safe in some instances?

was out of danger.   Two months later a couple of fresh mice were fed for several days upon mixtures of carbonate of baryta and whiting, and it appeared that the whiting acted as an antidote, to protect the mice from the poisonous effects of the barium compound.   For several days after their capture these mice received 4 balls of plain whiting-putty per day, and they ate the whole of it.   They were then given 4 balls of putty made from oil and a mixture of $\frac{1}{10}$ carbonate of baryta and $\frac{9}{10}$ whiting, but they ate only 2 of the balls during the first day.   Next day they received 4 fresh balls of the same baryta mixture and ate them all.   They were then given 4 balls of putty made from a mixture of $\frac{1}{5}$ carbonate of baryta and $\frac{4}{5}$ whiting, and they ate 3 of these balls.   Next day they got 4 balls of putty made from a mixture of $\frac{1}{2}$ carbonate of baryta and $\frac{1}{2}$ of whiting, but to all appearance they ate none of it. Next day they were given 4 balls of putty made from pure carbonate of baryta and oil, and although, so far as could be seen, none of the balls were touched, yet the mice both died on the following day.   A week or two later a mouse that had only just been caught escaped from his cage one night, and gained access to one of the last-named balls made of pure carbonate of baryta.   He carried this ball into a corner, and was found there next morning lying dead beside the ball, of which he had only eaten a small portion. For the sake of certainty this ball was analyzed and found to consist solely of carbonate of baryta and oil.

The protective influence above alluded to, of carbonate of lime against carbonate of baryta, is a noteworthy fact.   It goes to show that there may have been something of truth in the " fabled " electuary of Mithridates.   Further illustrations of the efficacy of the lime-carbonate as an antidote will be seen beyond, under the head of white-lead, and also in the experiments upon rats.   The action of it would seem to depend at first sight upon the more easy solubility of carbonate of lime * in the acid juices of the stomach. It might not unnaturally be supposed that while the lime compound goes into solution, the less soluble barium (or lead) compound is shielded from the acid solvent and passes off through the intestines as mere inert matter.   But if this explanation be a true one, the power of the mice to deal with such masses of carbonat · of lime as have been described above, becomes all the more extraor-

* " The 28 minerals which occur, as pseudomorphs in forms of carbonate of lime, are all less soluble than it is."   Bischof, " Elements of Chemical Geology," London, 1854, **1.** 39.

dinary. For if the lime-compound is really dissolved by the gastric juice, why is not the whole of this juice used up in dissolving the carbonate? How is any of it left to digest the natural food (oats in this case) of the animal? And how can the animals continue to live and thrive for weeks, as they do, if there is a great quantity of soluble lime salts (chloride and lactate of calcium) continually formed within them?

Carbonate of Lead. After the trials with mixtures of ochre and whiting, the mice were fed with pure putty and oats for a day or two and were then given putty with which a certain proportion of white-lead * had been mixed. During the first day the three mice ate 5 balls of putty made from a mixture of 9 grammes of whiting and 1 grm. of the lead carbonate, beside their regular ration of oats. Next day they were given 4 balls made from a mixture containing 1 part of the lead carbonate and 3 parts of whiting, but they ate only a small part of each of the balls. On the third day four fresh balls were given similar to those of the second day, and the mice ate between two and three of them. Three similar balls were given on the fourth day, but only a very small portion of them was eaten, and next morning one of the mice was found dead. The two remaining mice received nothing but oats and water during the next twenty-four hours in order to make sure of their viability, and they were then offered four balls made from a mixture of $\frac{1}{2}$ lead carbonate and $\frac{1}{2}$ whiting. They ate two of these balls. Next day they were given four balls made from a mixture of 3 parts lead carbonate and 1 part whiting, and they ate two of them. On the following day 4 similar balls were given and all of them were eaten. Finally the two mice were given four balls made from pure carbonate of lead, without any whiting, and a small quantity was eaten from each ball, perhaps as much taken altogether as would amount to one ball, but both the mice died in the course of the day.

It would be of interest, in this connection, to study the question whether the protective influence of the lime carbonate, or some other analogous compound, might not be put to practical use in the case of ordinary paints. May it not be possible, I mean, to " adulterate " white-lead in such wise that the colic of house-painters could be diminished or done away with? I am well aware

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* The material actually employed was chemically pure carbonate of lead, " *Plumbum carbonic. puriss.*," from Marquart of Bonn.

that the application of this idea would be beset with technical difficulties ; but it might be studied nevertheless.

During the foregoing trials with white-lead the mice continued to void light-colored dung, though the particles were not so large as those from whiting ; the color was moreover somewhat tarnished from the presence of a little black sulphide of lead. On analysis, this dung was found to contain an abundance of lead, and when dilute muriatic acid was poured upon the the dung enough sulphuretted hydrogen was given off to react freely upon paper that had been moistened with acetate of lead. But no reaction for sulphuretted hydrogen was obtained from dung that had been voided by the mice that were fed with whiting unmixed with white-lead.

Carbonate of Zinc. A couple of mice accustomed to an allowance of 4 balls of plain putty per day were given 4 balls of putty made from a mixture of 1 part pure carbonate of zinc and 3 parts of whiting, and they ate them all. Next day they were given 4 balls made from a mixture of equal parts of carbonate of zinc and whiting and they ate nearly all of them. On the following day, 4 more balls of the half and half putty were given, and one of the mice was found dead.

Oxide of Zinc. Two mice were given several balls made from a mixture of 1 part pure oxide of zinc and 3 parts whiting, and the balls were left in the cage during two days. Each day it could be seen that only a very small portion of the material had been eaten. But one of the mice died on the second day. A fresh mouse was put in the cage and the animals were fed with plain putty for three or four days, after which time they received each day, during three days, a couple of balls of putty made from a mixture of $\frac{1}{10}$ oxide of zinc and $\frac{9}{10}$ whiting. One of the mice died on the third day. A fresh ball of the same mixture was given to the remaining mouse every day during five days, and almost every day he ate a part of it, sometimes almost the whole of it, but he suffered no apparent harm. He was next fed with plain whiting-putty for a day or two, and afterward again with putty made from mixtures of oxide of zinc and whiting as follows : During five days he got each day a fresh ball made from $\frac{1}{4}$ oxide of zinc and $\frac{3}{4}$ whiting. Some days he ate very little of the mixture while on other days he ate a considerable portion of what was offered him ; meanwhile he remained lively and ate his oats with avidity. Every day during the next six days a couple of fresh balls of putty made

from 3 parts oxide of zinc and 7 parts whiting were put in the cage, but the mouse absolutely refused to eat any portion of either of these balls, although pains were taken to make the putty of various degrees of consistency, on the different days, by using more or less oil in preparing it.   In order to break up this habit of refusal a quantity of plain whiting-putty was given to the animal on the seventh day.   He ate a ball of it at once ; and on the following day, when a ball of the mixed oxide of zinc and whiting (3 : 7) was offered him, he ate a portion of that also and died the day afterward.

It was noticeable throughout these experiments that the dung of the mice that were fed upon zinc compounds was neither of large size, like that obtained from the really inert materials, nor was it so white as the dung from the other white materials.   It was light-colored, it is true, but its appearance was wholly unlike that obtained from whiting and the other materials.   There was nothing about it to suggest that it consisted of inert matters which had simply passed through the animals.   On the contrary its appearance indicated that the zinc compounds must undergo changes in the bodies of the animals, such as the other materials were not subjected to.

Slaked Lime.   Several balls of putty made from powdery slaked lime and oil were offered to a lot of three mice, but only a small portion of one of the balls was eaten.   Next day three balls made from a mixture of equal parts of slaked lime and whiting were given.   All but half of one of the balls of this mixture was eaten, and one of the mice was found dead.   The surviving mouse refused to eat any more of the mixture, and the experiment was carried no further.

Whiting and Syrup.   Instead of putty proper, a couple of mice were fed for several days with mixtures of whiting and a strong solution of sugar made up into balls of the consistence of ordinary putty.   The mice ate the mixture freely, and their dung seemed to be even whiter than any that had been previously observed. The cylinders of dung seemed on a cursory examination to be of rather smaller size than those from the putty proper, but no pains were taken to verify this supposition by actual measurements.

Experiments with Rats.

A few trials were made with rats in order to see whether the results obtained in the experiments with mice were applicable to the rat as well. It was found that the rats when kept upon a rather short allowance of oats ate putty freely, and voided great cylinders of white dung. For example, a single rat of 134 grms. weight ate no putty when fed for a couple of days in June upon 8 grms. of oats per day, but on putting a second rat into the cage and giving the two animals 4 grms. of oats and 20 grms. of putty ($=$ 6 balls) they ate the whole of it, and the same result was obtained next day on repeating the last-named trial. Next day the animals were given 6 balls of putty made from a mixture of $\frac{1}{10}$ carbonate of baryta and $\frac{9}{10}$ whiting, and 8 grms. of oats, and they ate only 3 of the balls. The same result was obtained on the day following with the same ration, although another small rat had been put in the cage. Next day the three rats received 6 balls of putty made from a mixture of $\frac{1}{5}$ carbonate of baryta and $\frac{4}{5}$ whiting, together with 8 grms. of oats, and no more than 4 of the balls were eaten. On the day following another large rat was added, and 6 balls of a mixture of equal parts of carbonate of baryta and whiting were put in the cage, together with 9 grms. of oats. Only one of these balls was eaten, but one of the rats was found dead. Finally several balls of putty made from pure carbonate of baryta were given to the animals, and although none of them seemed to have been eaten,[*] another rat was found dead. The remaining rats were fed for several days with simple whiting-

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[*] In experimenting with rats it is difficult to tell how much of the offered material has really been eaten, since the restless animals tumble the balls about, trample them in the dirt of the cage, and crush them beyond recognition.

Another difficulty encountered in experimenting both with rats and with mice is that when one of the animals dies, his body is soon eaten by the survivors, who thus become gorged with food and indisposed to consume the experimental rations. This craving for flesh is, however, no evidence that the animals were suffering acutely from hunger, for the same thing occurs constantly in ordinary life, where mice have no access to animal food. I have repeatedly seen the bodies of mice that had been strangled in a spring trap eaten off at the back of the head in the course of a few hours even in granaries and places where there was an abundance of vegetable food, and in places moreover where no rats where to be found. The fact does but enforce the wisdom of the popular notion that traps for rats and for mice should be baited with meat.

putty and oats in order that they might recover from the ill-effects of the barium compound, and were then put upon rations of white lead, as follows: Three balls of putty made from pure white lead, and 7 grms. of oats, were given to the three animals. They apparently ate a little of the putty; but the material was so sticky that it must have been repulsive, and in order to avoid this difficulty, enough sulphate of baryta was worked into the balls to give them a firm subsistence. They were then replaced in the cage, and next morning it could be seen that a small portion of one of the balls had been eaten; in fact, one of the rats was found dead, and on the day following another of the animals died. It was plain that, as had been the case with the mice, the rats were readily destroyed by white-lead when there was no whiting present to shield the animals from the poisonous action.

The surviving rat was fed with plain putty for a day or two, after which time he received and ate each day for two days a ball of putty made from a mixture of equal parts of slaked lime and whiting. He was next given a ball of putty made from a mixture of 1 part oxide of zinc and 3 parts whiting, together with $2\frac{1}{2}$ grms. of oats, and although he ate very little of the ball, he died soon afterward.

I was much indebted to my friend, Mr. L. S. Ford, for assistance in carrying out the details of these experiments. He was a student at the Bussey Institution at the time (1877–78) they were made.

July, 1878.

No. 25. — *Experiments on Feeding Plants with the Nitrogen of Vegetable Mould.* By F. H. STORER, Professor of Agricultural Chemistry.

In a paper* published in 1874 I insisted at some length upon the importance as plant-food of the nitrogen in vegetable-mould. Subsequently it occurred to me that the experiments recorded in that article might be made still more emphatic by mixing the vegetable-mould to be tested, not with mere sand and coal-ashes as then, but with a garden soil from which the whole of the original organic matter had been removed by careful calcination. Such earth would naturally contain all kinds of food needed by plants, with the single exception of nitrogen; and it was to be expected that plants would grow in it readily whenever the lacking nitrogen was supplied. It might even be possible to obtain in this way some quantitative indications of the value of the soil-nitrogen by proceeding methodically and mixing with weighed quantities of the calcined loam several definite, increasing amounts of the vegetable-mould to be examined.

In order to test this idea, the following experiments were carried out in the glasshouse of the Bussey laboratory in the winter of 1877–78. A quantity of good dry loam from the garden of Mr. R. Beatley, Chelsea, Mass., was calcined at the temperature of low redness in a large iron muffle capable of carrying two or three pounds of the material at a charge. For convenience and the saving of time spent in calcining, as well as for the sake of improving the texture of the rather too compact calcined earth, a quantity of Berkshire sand† was mixed with it before proceeding with the actual experiments.‡ The experiments were made in wide-mouthed glass jars (preserve jars) in the same general way as the experiments previously described in this Bulletin.§ The mixtures of sand and calcined loam were made jar by jar; the amounts of materials recorded below being weighed out for each

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* "Bulletin of the Bussey Institution," **1.** 252.

† See Bussey Bulletin, **1.** 59.

‡ As was done in an earlier series of experiments with roasted leather, described on page 61 of Vol. **2.** of this Bulletin.

§ Compare Vol. **1.** pp. 54, 253.

particular jar and carefully mixed upon a glass plate before the loam proper was added.

There were four sets of jars, each of five pieces, with the exception that one set consisted of six jars. The vegetable-mould tested was in the form of loam, of the same sorts that had been employed in earlier experiments of one kind and another in the Bussey laboratory. In the first set of jars loam from the garden of Mr. R. Beatley, Chelsea, Mass., was used; in the second set loam from an old pasture of Mr. Henry Saltonstall, Lynnfield, Mass.; in the third set loam from the Plain-field of the Bussey Institution; * and in the fourth set loam from an experimental plot upon the Plain-field upon which crops of beans had been grown during four consecutive years before the loam was collected.† It will be seen on inspecting the tables that each of the given kinds of loam was employed in several different proportions.

Three buckwheat seeds were sown in each jar on the 17th of November, 1877, and all the jars were watered with rain-water, and nothing else, from first to last. For the pieces numbered III., which, with one exception, carried an unusually large quantity of the materials, pains were taken to select jars that were known to be a little more capacious than the others: while for the jars numbered IV. and V. somewhat smaller quantities both of the sand and of the calcined earth were weighed out than for Nos. I., II., and III., in order to make room for the increased quantities of the loams proper. The experiments numbered IV. and V. are consequently not so exactly comparable with Nos. I., II., and III., as might be wished, though the differences are really small and probably insignificant.

Each of the crops was dried at 90° to 100° C. before weighing. The other details of the experiments will appear from the tables.

* This Plain-field loam was collected before any experiments had been made upon the field.

† This "Bean-plot" loam was taken from the plot marked "B. 5 Beans," in the series of experiments described on pages 88, 140, 315 of Vol. 2. of the Bulletin, and was selected as an example of soil that had been severely cropped.

First Set of Jars : — Loam from Mr. Beatley's garden.		Crops harvested Feb. 16, 1878.		
No. of the Jar.	Contents of the Jars.	Weighed in grammes.	Grew to height in inches.	Had seeds.
0	Nothing but 560 grms. Calcined Loam and 760 grms. Berkshire Sand	0.300	5½	1
I.	560 grms. Calcined Loam, 760 grms. Berkshire Sand, and 25 grms. Simple Loam from Mr. Beatley's garden	0.502	{ 5½ 6¼ 9 }	1
II.	560 grms. Calcined Loam, 760 grms. Berkshire Sand, and 50 grms. of Loam from Mr. Beatley	0.610	{ 6 7 9 }	0
III.	560 grms. Calcined Loam, 760 grms. Berkshire Sand, and 100 grms. of Loam from Mr. Beatley	0.515	{ 7 10 } *	3½
IV.	500 grms. Calcined Loam, 680 grms. Berkshire Sand, and 150 grms. of Loam from Mr. Beatley	2.260	{ 10½ 10½ 13 }	13, and many flowers.
V.	500 grms. Calcined Loam, 680 grms. Berkshire Sand, and 200 grms. of Loam from Mr. Beatley	1.010	{ 6 9 10 } †	1, and many flowers.

* Only two plants.
† The plants in this jar never grew very well. The earth was probably too compact.

Second Set of Jars : — Loam from Mr. H. Saltonstall's pasture.		Crops harvested Feb. 16, 1878.		
No. of the Jar.	Contents of the Jars.	Weighed in grammes.	Grew to height in inches.	Had seeds.
I.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 25 grms. Simple Loam from Mr. Saltonstall's pasture ·	0.435	{ 5 7 7½ }	0
II.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 50 grms. of the Loam from Mr. Saltonstall	0.460	{ 7 8½ 9½ }	Several immature.
III.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 100 grms. of the Loam from Mr. Saltonstall	0.565	{ 6 7½ 9½ }	3 ·
IV.	500 grms. Calcined Loam, 680 grms. Berks. Sand, and 150 grms. of the Loam from Mr. Saltonstall	1.265·	{ 7½ 10 12½ }	7, and some flowers.
V.	500 grms. Calcined Loam, 680 grms. Berks. Sand, and 200 grms. of the Loam from Mr. Saltonstall	1.270	{ 10 11 12½ }	4, and many flowers.

Third Set of Jars: — Loam from Bussey Plain-field.		Crops harvested Feb. 16, 1878.		
No. of the Jar.	Contents of the Jars.	Weighed in grammes.	Grew to height in inches.	Had seeds.
I.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 25 grms. Loam from the Plain-field	0.390	7½ 8½ 9	0
II.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 50 grms. Loam from Plain-field .	0.445	6½ 8 8½	0
III.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 100 grms. Loam from Plain-field	0.710	6 11 11½	5
IV.	500 grms. Calcined Loam, 680 grms. Berks. Sand, and 150 grms. Loam from Plain-field	1.550	5 12½ 15¼	10, and some flowers.
V.	500 grms. Calcined Loam, 680 grms. Berks. Sand, and 200 grms. Loam from Plain-field	1.750	12 13 15	7, and some flowers.

Fourth Set of Jars — Spent Loam from the Bean-plot.		Crops harvested Feb 16, 1878.		
No. of the Jar.	Contents of the Jars.	Weighed in grammes.	Grew to height in inches.	Had seeds.
I.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 25 grms. of the Bean-plot Loam.	0.310	6 7½ 7½	1½
II.	560 grms. Calcined Loam, 760 grms. Berks. Sand, and 50 grms. of the Bean-plot Loam	0.450	6 8 9½	0
III.	500* grms. Calcined Loam, 680* grms. Berks. Sand, and 100 grms. of the Bean-plot Loam	1.140	9 10½ 12	1, and some flowers.
IV.	500 grms. Calcined Loam, 680 grms. Berks. Sand, and 150 grms. of the Bean-plot Loam	1.150	8 10 11½	15, and some flowers.
V.	500 grms. Calcined Loam, 680 grms Berks. Sand, and 200 grms. of the Bean-plot Loam	1.475	7 13 13	7

* The numbers (500 and 680 grms.) are correct for this special instance. They were chosen in this case because of the lack of a jar large enough to hold the usual mixture.

It will be seen at a glance that the figures representing the crops obtained are not perfectly regular and consecutive. There are many small irregularities to be noticed in all parts of the tables. But it is nevertheless true, that there can be no question as to the general result. Noteworthy crops of buckwheat were grown namely upon calcined loam to which no fertilizers were applied, and which received no nitrogenous food excepting that contained in the small proportion of ordinary loam which was added. Moreover better crops were obtained in general in proportion as the amount of ordinary loam employed was larger. These facts were

conspicuous to the eye while the crops were growing. On the 26th of January, 1878, three weeks before the plants were harvested, I wrote the following statement in my note-book : —

"The differences between the high and low numbers in this series of experiments is very marked, as it has been all along. The jars numbered IV. and V. have large healthy plants bearing flowers and seeds, while the plants in Nos. I. and II. are small and well-nigh flowerless. The crops in No. III. are mediocre. There are, of course some exceptional jars among the higher numbers, in which the plants have not prospered, doubtless because of too wet or too compact soil, or, as one may say, on account of ' improper tillage.' But so far as the general appearance of the bench goes, the gradation of crops is really perfect and unbroken from Nos. 0 and I. to No. V."

For the sake of more convenient comparison I have rearranged in the following short table the

WEIGHTS OF DRY CROP HARVESTED.

Names and Nos. of the Sets of Experiments.	Nos. of the Jars, and weights of real Loam in each; the last-named figures in the parentheses.				
	0.	I.	II.	III.	IV.	V.
		(25 grms.)	(50 grms.)	(100 grms.)	(150 grms.)	(200 grms.)
1. Beatley Loam . .	0.300	0.502	0.610	0.545	2.260	1.010 ·
2. Saltonstall Loam .	—	0.435	0.460	0.565	1.265	1.270
3. Plain-field Loam .	—	0.390	0.445	0.710	1.550	1.750
4. Bean-Plot Loam . .	—	0.310	0.450	1.140	1.150	1.475
Sum of the weights of the crops . .	—	1.637	1.965	2.960	6.225	5.505
Average weight of the crops . . .	0.300	0.409	0.491	0.740	1.531	1.361

It should be said that numerous experiments, some of which will be published in a subsequent article, had shown that mixtures of calcined loams and sand, such as formed the bulk of the soil in these trials, are capable of bearing abundant crops of buckwheat when supplied with nitrogenized fertilizers such as the nitrates of potash and of lime.

I offer the foregoing experiments merely in confirmation of my previous proof that the nitrogen of the soil is of very great value as plant food under the ordinary conditions of warmth and moisture that are proper for the growth of agricultural plants. But I may here say that I have not gained from these experiments any encouragement to pursue another enquiry which had suggested itself to me ; namely, whether it might not be possible to test ·(*i. e.* "assay") the nitrogen-value of any given soil by mixing small quantities of it with a standard calcined earth, and growing crops upon the mixtures. In experiments such as the foregoing

there are so many influences working to impair the nicety of the results that it would be extremely difficult, if not impossible, to attain that high degree of accuracy which would be needful for the case in point. I have consequently been forced to abandon this line of enquiry.

It should be said that there is good reason to believe that the diversity of results just now spoken of may depend for the most part upon a greater or less degree of activity in the process of nitrification in the contents of the several jars. That is to say, the organism or ferment,* upon whose presence nitrification depends, may have been better suited by the conditions of the earth in one jar than in another, and have prospered or languished accordingly.

It is manifest that in carrying out experiments of this sort the purely chemical part of the enquiry becomes complicated with the question how best to care for the ferment organism, and how to control its growth so that it shall be equal in all cases or, at the least, comparable. Indeed, one the first things now to be done in seeking to explain the agricultural value of the nitrogen in vegetable-mould is to determine precisely what the ferment organism is, and to study its habits and the history of its development. When this knowledge has been gained, it will doubtless be practicable for the farmer to employ the soil-nitrogen in a much more intelligent way than has been customary hitherto. He will then be able to count definitely upon the soil-nitrogen as a resource in a sense that was hardly to be thought of by his predecessors.

Many methods of tillage and of manuring, and some modes of mulching, — the conduct of which is now purely empirical, — and the whole subject of composts made with peat and loam, will undoubtedly then be brought into the domain of reasonable practice. For example, the question is now open whether the well-known power of clover and root-crops to supply themselves with nitrogen may not really depend upon the comfort and shelter these crops offer to the nitrifying ferment. It is not unlikely that the ferment organism may prosper exceedingly beneath the dense shade of clover and other large-leaved plants, in the comparatively moist surface-soil which is peculiar to such fields. Perhaps even the manner in which the roots of these plants act upon the soil may have a favorable influence upon the life of the ferment? There is an old ex-

* See "American Journal of Science," April and June, 1878, **15.** pp. 310, 444.

periment by Gazzeri * which bears upon this point. He weighed out into similar vases two four-pound portions of artificial earth that had been deprived of organic matters, and he mixed with each of these quantities of earth four ounces of a horse's hoof cut into small fragments. Two beans were planted in one of the vases while the soil of the other was left unsown. During the growth of the beans, which was very vigorous, the two vases were treated in precisely the same way. When the bean-plants had ripened and become almost completely dry they were removed from the vase, the earth was thrown upon a hair sieve dipped in a tub of water and gently kneaded to make it pass as a thin pap through the sieve. As nothing remained upon the sieve Gazzeri concluded that the fragments of hoof had been completely decomposed. But on subjecting to a similar operation the earth from the other vase, in which nothing had grown, a number of fragments of hoof were found upon the sieve. They were soft and, as it were, soapy. After drying them, they weighed twenty-two grains; whence it appeared that of two equal quantities of hoof otherwise exposed to similar conditions, the one in contact with bean-roots had been completely decomposed while the other left in mere earth was only partially consumed.

So, too, in the case of Indian Corn, a plant which grows vigorously in hot weather, it is probable that its observed power of utilizing the soil-nitrogen to better advantage than the small grains can.†

* "Bibliothéque universelle de Genève" (Agriculture), 1821 (N. s.), **6**. 181.

† Compare Professor Atwater's experiments in "American Agriculturist," May, 1879, **38**. 178. It is interesting to note, in this connection, the importance which some of the old agricultural writers attached to maize when regarded as a "fallow crop" fit to precede the small grains. Thus, Arthur Young, in his "Travels in the Kingdom of France," Dublin, 1793, Vol. **2**. page 137, says: "In travelling southward, it is a remarkable circumstance that fallows never cease till maize is met with; but that afterwards this plant becomes the preparation for wheat in the course: 1, maize; 2, wheat." . . .
And again, on pages 139, 140, he says: "The most singular circumstance is the infinite importance of the culture of maize. From Calais to Quercy you never once quit fallows; but no sooner do you enter the climate of maize, than fallows are abandoned, except on the poorest soils; this is very curious. The line of maize may be said to be the division between the good husbandry of the south and the bad husbandry of the north of the kingdom. Till you meet with maize, very rich soils are fallowed, but never after; . . . it is succeeded by wheat."
So, too, Jared Eliot, in his "Essays upon Field-Husbandry," page 92 of the edition printed in 1811, by Mass. Soc. for Promoting Agriculture, says,

will be found to depend upon some peculiarity of the crop which promotes the growth of the nitric ferment in the soil beneath it, and so makes the nitrogen of the vegetable-mould available as plant food.

The making of composts in particular (from earth and dung) may soon cease to be regarded as a subject of technical chemistry, and the consideration of the theory of composting may pass from the chemist's hands into those of the botanist or biologist. For, accordingly as the ferment organism is found to be a cryptogamic plant or a minute animal, the process of compost-making will come to be looked upon either as a horticultural operation, like the cultivation of mushrooms, or a question, as one may say, of stock-raising. When the proper rules have been discovered, the compost-maker will doubtless rear the ferment organism in special beds and sow the spawn upon the compost-heap in some definite and methodical way; or, in many cases perhaps, he may sow the ferment germs directly upon the soil of the fields which are destined to bear grain or some other agricultural crop.

I have myself recently noticed in field practice a striking instance where the spreading upon grass of loam which was presumably charged with the ferment organisms did manifestly supply the grass with some kind of active nitrogen. The observation was as follows: in building a gravel road for an avenue across the Plainfield, a small depression upon the surface of the land was filled up with loam taken from the bed of the avenue, in such manner that there was a thick layer of loam, perhaps two or three feet deep, close beside the nearly flat avenue at its lowest point, where the rain-water flowed from it. After the loam had lain in this position undisturbed for four years, covered all the while with a thick mat of grass, a quantity of the loam was removed in early summer from

in 1747, when insisting upon the importance of tilling Indian corn thoroughly (a process, by the way, which probably promotes nitrification), "What is still more remarkable, if the Indian corn be well tilled the next crop, whether it be oats or flax, so much the bigger and better will that succeeding crop be, so that the land must have gained strength and riches; if it were not so, why did not the Indian corn exhaust and spend the strength of the land, especially when we consider how large corn is made to grow by the good tillage? But we find the contrary, the better the crop of Indian, the better will be the crop of oats."

Manifestly, the old French practice of taking a crop of maize before wheat, and that in the face of a popular tradition that wheat should follow a bare fallow, is pretty good evidence that a maize crop must leave behind it in the soil some kind of available nitrogenous food.

beneath the grass, and spread in a narrow stripe upon another part of the field. It was spread, namely, in a grass-grown dead furrow in the shade of a large stone building, where the grass was thin and miserable. But it was seen almost immed ately that the strip of grass upon which the loam was scattered had begun to grow luxuriantly, and had taken on the deep green color which is so characteristic of the presence of active nitrogenous manures, and the good effects of the application were visible throughout the entire season. Inasmuch as the original loam of the field had not received any application of dung for years, and that the amount of dung dropped upon the avenue was extremely small ; since, moreover, the same kinds and amounts of chemical fertilizers had been applied in past years as a top-dressing both to the soil of the dead furrow and that of the loam-bed, and since the soil of the loam-bed had not received any application whatsoever of fertilizers for more than a year, although four or five cuttings of tall grass had been carried away from it ; I was not a little surprised at the great activity of the nitrogen in the scattered loam. Since the loam was spread so thinly that it could hardly have acted as a mulch, the most plausible explanation of its activity was, that the bed of loam reposing upon loose gravel,* and so situated that it is thoroughly moistened by every fall of rain, is a natural nest of the organisms which cause nitrification. On transplanting a quantity of these organisms they induced fermentation in the soil of the dead furrow, to the manifest advantage of the vegetation there situated.

All this is, of course, nothing more than happens when a well-fermented, thoroughly-rotted peat compost is applied to the land ; and the growth of the nitric ferment in such compost explains the riddle of Lord Meadowbank, who found long ago that one part of dung is sufficient to bring three or four parts of peat into a state in which it is fitted to be applied to the land as if it were itself manure.

In the same sense may be explained also an expression of the Parisian gardeners, who, as Boussingault † tells us, use some part of the well-rotted compost (*terreau*), prepared for their forcing-beds, as a top-dressing for grass in pleasure-grounds, and say that the purpose of it is to compost (*terreauter*) the sod.

September, 1879.

* Bussey Bulletin, **1.** 80.
† In his " Agronomie, Chimie Agricole et Phisiologie," Paris, 1861, **2.** 12.

No. 26. — *Experiments on the Germination of Weed Seeds.* By F. H. Storer, Professor of Agricultural Chemistry.

In connection with some of my earlier experiments on growing plants in pots filled with coal-ashes and sands of various kinds, attempts were made, incidentally, to germinate the seeds of certain weeds. My intention was to discover. if possible, among our common weeds some one kind. or several kinds, that could readily be grown in pots in the glass-house, with a view of testing experimentally, by the vigor of growth of the plants, the capacity of very poor soils to support vegetation; and for the purpose, also, of comparing one kind of soil with other kinds, as to its natural " strength" or value.

The seeds experimented upon were all gathered in the vicinity of the Bussey Institution, as soon as they were ripe, in the autumn of 1872, and they were set to germinate a few weeks later in a glass-house, the temperature of which was permitted to range from 48° or 50° F. at night to 68° or 70° by day. A number of seeds were selected and put to soak in water for twenty-four hours; they were then placed in a common flower-pot saucer of unglazed earthenware, which was set in a larger saucer that was kept filled with water up to the rim of the smaller inner saucer, which contained the seeds. This double saucer arrangement was kept covered with an inverted flower-pot large enough to enclose the apparatus completely, and to rest upon the table without touching the outer saucer.

I have retained memoranda of the following trials : —

Polygonum acre (Water Smart-weed). Of 150 seeds placed in a germinator saucer on October 11th, 1872, none had germinated on November 1st; and it appeared at this time that many of the seeds had become mouldy. A second lot of the seeds was then placed in another clean saucer and treated as before, with the result that none of the seeds sprouted, that they all became mouldy after a while, and were finally thrown away.

Polygonum persicaria (Spotted Knot-weed). Of 150 seeds placed in a saucer on October 11th, none had germinated on October 18th; but nearly a third of them had germinated by November 11th, while the remainder were so mildewed that they

were thrown away. A similar result was obtained on repeating the experiment.

Lappa officinalis, var. *major* (Burdock). Of 50 seeds placed in a saucer on October 11th, two sprouted on October 24th, and others thereafter.

Bidens chrysanthemoides (Larger Bur-marigold). Fifty seeds set to germinate came to naught, and were finally thrown away.

Ambrosia artemisiæfolia (Ragweed). An unlimited number of the seeds were set to germinate on October 19th. On November 11th it appeared that only eight of them had sprouted, and that most of the remainder were mildewed ; and a repetition of the experiment gave an equally unfavorable result.

Setaria glauca (Bottle-grass). 150 seeds put to germinate on October 11th came to nothing, and were thrown away.

These results were so unlike those obtained at the same time with various kinds of grain, and with other agricultural seeds, — which germinated readily enough, and were especially in such marked contrast with the behavior of some barley which I had germinated a few months earlier at the temperature of freezing water,[*] — that I regarded the experiments as failures, and attributed my lack of success to the fact that the temperatures at which the germinator saucers were kept were by no means high. To all appearance these temperatures were too low for the germination of some, at least, of the seeds in question. It is to be remembered that many of our commonest weeds are tropical plants, and that most of the seeds in my experiments (burdock and *persicaria*, perhaps, excepted) came from plants that flourish during the hot weather of the later summer months.

From these considerations, I inferred that both the seeds and the plants needed higher temperatures than those at which my glass-house was maintained, and that, consequently, they were unfit for the proposed experiments. Some of the burdock-seeds germinated readily enough it is true, but the growth of the young plants is so slow that I was not encouraged to continue to experiment with them. It appeared as if this biennial plant was, during the first year of its life, merely getting ready to grow in the second year, hence no further attempts were made by me to induce the seeds of weeds to germinate. It appears, however, from the re-

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[*] " Bulletin of the Bussey Institution," **1.** 52. This observation has been repeatedly made by other experimenters.

cent elaborate and methodical trials of Haenlein* at Tharand, that the seeds of many other kinds of weeds are extremely sluggish and difficult to germinate; and that the results of my old experiments are perhaps not wholly worthless, since they add a few new particulars to Haenlein's list. The only plant common to his trials and my own is the knot-weed (*Polygonum persicaria*), the seeds of which behaved with him much in the same way they did with me. In Haenlein's trial 13 per cent of the seeds of this plant germinated in the course of eight days; and, in an earlier experiment by Nobbe and Haenlein, 7 per cent germinated in fifteen days.

Although it has been made plain by the work of the Tharand observers that much more than a few days, or months even, is needed in order to determine whether a given sample of weed-seeds is capable of germinating; and although it has been made manifest that there are other conditions and circumstances beside the influence of air, warmth, and moisture, which are essential to the speedy germination of many kinds of seeds; there is still small reason to doubt the conception that tolerably high temperatures must be essential to success in many instances, and there are some reasons for believing that abundant warmth, at the moment of germination, may be of paramount importance in certain cases. Several of the practices of gardeners enforce this idea; such, for example, as the habit of "starting" in hot-beds or in special boxes which can be kept warm, the seeds of many plants of southern origin, and the steeping also of various kinds of seeds. I have myself noticed that some of our New England farmers habitually resort to artificial heat for germinating the seeds of squashes. An approved method is to place in a milk-pan a quantity of the damp vegetable mould that collects in hollow apple trees, through decay of the wood, to sow the squash seeds in this earth, and to place the pan in a warm position near the kitchen stove until the seeds have started, when they are transferred to the soil of the field. So, also, the practice, common among gardeners, of putting certain leguminous seeds into boiling water, to awaken their dormant energies, may perhaps point to the existence, for all seeds, of a definite, necessary temperature to which the seeds must be brought before the act of germination can begin. It would be but natural that this starting temperature should be exceptionally high in the case of tropical and hot-weather plants.

February, 1881.

* "Die landwirthschaftlichen Versuchs-Stationen," 1880, **25.** 465.

No. 27. — *Description of an Attempt to Assay Soils by the Method of Sand Culture.* By F. H. STORER, Professor of Agricultural Chemistry.

THE idea of testing the chemical power or value of a soil by growing plants in it directly, either with or without addition of chemical substances, is a very old one. It has often been acted upon in the laboratory * and multitudes of field experiments have been based upon it. So, too, processes of growing plants in sterile sand admixed with one or more chemical substances necessary for the support of plants, have for many years played an important part in the investigation of problems relating to the chemistry and physiology of vegetable growth.

During many years I was of opinion that some combination of these two methods might be devised, which should be applicable for the practical testing or assaying of soils. I pictured to myself a simple, methodical, trustworthy method of research by means of which anyone having control of a greenhouse should be able, without much trouble, to determine the intrinsic value of a given soil, in so far as its value might depend upon the presence or absence of plant-food, and to form a just opinion as to the kinds of manure most neeeded by it. On being called to take charge of the Bussey laboratory, and thus finding at last opportunity to test this opinion, I have spent a great deal of time and labor in doing so, with the result that I have been forced to modify my former conception very materially.

The chief difficulties in carrying out the idea in question depend upon the extreme ·delicacy and sensitiveness of the method of research, and the unlikeness of its conditions to those which are found in actual farm practice. Many worthless sands, coal ashes, and " exhausted " loams will, when properly watered, bear good crops,† provided the plants are shielded from harm and made comfortable in respect to heat and cold ; and when these outward conditions are favorable, extremely little if any additional plant-food is needed to make an " exhausted " loam support as good plants as a soil which is known, from experience in the field, to be fairly fertile. Under the favorable conditions of the pro-

* Notably by Salm Horstmar, Daubeny, Boblerre, and Ville.
† See Bussey Bulletin, L. 50, 252.

posed assay a poor soil will give good, and a mediocre soil excellent crops ; and I have found it extremely difficult if not impossible to discriminate between several samples of cultivable earths, unless indeed they were very different in reality.

A striking illustration of the power of a loam of poor quality to supply plants with food, provided it be kept continually moistened, was afforded by an experiment in which Indian corn was grown in two contiguous jars, one filled with loam from Mr. F. H. Appleton's farm, at Lynnfield, Mass., and the other with Berkshire County sand. Two kernels of common yellow maize were planted in each jar, January 18, 1873, and after the young plants had appeared, the jar which contained the loam was watered with nothing but rain-water, while the sand jar was watered with a mixed solution of the nitrates of lime and potash, phosphate of potash and sulphate of magnesia. The plants prospered in both jars ; all of them were healthy and vigorous, and they grew as well as could be expected in so cool a house.* When the experiment was interrupted on the 29th of April, each of the loam-grown plants was seven inches high, while the sand-grown plants were seven and fifteen inches high, respectively. But on being dried and weighed it appeared that, while the crops grown in mere loam watered with rain-water weighed 3.42 grms., the sand crop, which had received an abundant supply of a complete mixture of plant-foods, weighed no more than 3.51 grms.

In discussing any method of testing soils upon this plan, it is always to be remembered that the so-called fertility of a given field depends upon many other circumstances beside the proportion of chemical constituents which are contained in the soil. In actual farm practice the difference between a fresh and an " exhausted " soil depends often enough upon some purely physical dissimilarity. For example, the particles of the exhausted soil may have passed into such a condition of aggregation that they can no longer lift or hold enough capillary water for the needs of the crop, and in this case the plant would naturally suffer from lack of food in default of the vehicle by which the food is transported. But in the carefully watered jars of the experimental assay this difficulty, though of the gravest practical importance in the field, might be wholly eliminated. So, too, in respect to the

* In all my experiments the temperature of the glass house has been kept, as nearly as might be, at 48° to 50° F. by night and 68° to 70° by day.

soil-nitrogen, as I have explained in another paper.* In the assay of any loam by·the proposed plan the conditions would usually be tolerably favorable for nitrification, and perhaps very nearly equally so in all cases, while in the field the conditions are in some instances favorable for nitrification and in others adverse, and the loams are, practically speaking, fertile or sterile accordingly.

It is of course conceivable that some useful modification of the process may hereafter be devised, perhaps for example by the use of plants of such extreme sensibility, that they will grow in some classes of soils and not in others; but for the present I am forced to the conviction that considered merely as an "assay" my process teaches nothing but what could be learned, with vastly less trouble, by means of chemical analysis. I have found, in short, that while it is easy to prove by the assay that soils reputed poor really contain large quantities of plant-foods which only need opportunity in order to become available for the support of crops, it is extremely difficult to judge by means of it between several poor or several rich or several mediocre soils in such wise that the verdict shall be of the least use for the farmer.

The plan of the proposed assay was as follows : —

Instead of growing plants directly in the soil whose character is to be determined, the idea was to take a quantity of pure siliceous sand or other absolutely inert material as the standing room in which the plant should grow; and to mix with this sand a small portion (or several small portions) of the soil to be assayed, precisely as if this soil were a chemical substance of unknown composition whose action towards the plant we wished to test. A series of glass jars (ordinary wide-mouthed green-glass preserve jars in most instances) were charged with the mixture of sand and soil, seeds were sown in each jar, and the contents of the jars were kept moist with pure water until the young plants were well started. Henceforth the jars were watered methodically with highly dilute solutions of chemical substances, each jar being watered with its own special solution, and the several solutions being compounded in such wise that to some one at least of the jars there should be supplied whatever kind of plant food the soil might lack.†

In the earlier trials a number of different chemicals or mixtures of chemicals were employed in this sense, but one or another of

* Bussey Bulletin,.2. 280.
† Compare Bussey Bulletin, 1, 54.

them was discarded as the work went on and experience showed that it was not absolutely needed. This plan of employing the chemicals in solution was found to work much better in practice than the old one of mixing dry chemicals with the soil before planting. I have found that the plants are much more apt to be distressed by the chemicals when the latter are mixed with the earth in the beginning, than when they are applied day by day in the form of highly dilute solutions. Indeed I have rarely seen my plants suffer from the chemicals with which they were watered excepting in some extreme instances, where instead of a true soil of fit capillary character the plants were made to grow in materials, such for example as coarse fragments of bone-black, anthracite cinders or clippings of mica, that were lumpy as well as poor and inert in the chemical sense. Naturally enough, it sometimes happened that plants were seen to be distressed by chemicals in preliminary trials that were made to test the availability of some particular solution rather than to study the character of the soil in which the plants were standing. It would be easy in any event, in case the growing crops began to be distressed by the chemicals, to substitute rain-water for the chemical solutions, for as many days as might seem fit. Or if danger of this sort were anticipated, a small measured quantity of the chemical solution might be given the plants once a day or every other day, while rain-water was used for the watering, properly so called. Practically I have seldom found any difficulty in using the solutions of chemicals. The assay would be a capital method of research if all its requirements could be fulfilled as easily as this one. Of course by measuring the solutions it is easy to determine just how much of each chemical substance has been used in each of the jars. Definite quantities of food might readily have been given, in this way, to the plants on the soils under examination, if there had been the least encouragement to do so.

I have found that the pure white sand from Berkshire County, Mass., which is obtainable at the glass works of this vicinity, is tolerably well adapted for my experiments; and have satisfied myself by repeated trials that rain-water collected from the slated roof of a building, which like the school building of the Bussey Institution stands by itself in the country, is abundantly pure enough for the purposes of the assay. The water in question, which is stored in a large covered cemented brick cistern from which only insignificant quantities are taken for use, has proved

to be of remarkably constant composition and is probably really better adapted for my experiments than distilled water would be, in view of the difficulty of freeing the latter from ammonia compounds and of obtaining large quantities of it in a state of absolute purity.

After numerous trials with other plants, I finally chose buckwheat as a proper plant for the assay, since it has tolerably small seeds, grows quickly, can live in very poor soils and is better able than many other plants to support the hardships incidental to confinement and partial starvation.

The sands and earths, excepting those which had been calcined, as will be explained hereafter, were always taken in the air-dried condition.   And in all cases the crops were dried at 90° to 100° C. upon a steam table.

A record of some of the results actually obtained will serve better than anything else to exhibit the limitations of the process.* For example, the results of trials made with loams admixed with sand and, for the sake of comparison, with pure loams were as follows : —

No. of jar.	Harvest, 17th March, 1873. The loams were watered with	The crops from PLAIN-FIELD LOAM.				The crops from MR. APPLETON'S LOAM.			
		Weig'd grms.	H'ght in inches.	Had seeds.	Consisted of how many plants.	Weig'd grms.	H'ght in inches.	Had seeds.	Consisted of how many plants.
1	Nitrate of potash . .	2.38	9–15	23	5	1.34	11–12	32	6
2	Sulphate of magnesia .	3.36	14	25	3	2.15	11–16	29	6
3	Nitrate of lime . . .	4.87	10–19	60	5	2.25	10–13	39	7
4	Nitrate of potash and sulphate of magnesia	4.40	13–17	44	5	2.49	11–14	48	5
5	Rain-water	3.60*	13–21	62	5	2.19	8–17	25	5
6	Nitrate of ammonia .	3.13	14–16	28	4	1.89	9–18	34	5
7	Phosphate of potash .	3.90	12–14	37	2	4.14	11–15	22	6
8	Nitrate of lime and phosphate of potash	8.97	17–23	70	5	5.13	11–15	65	3
9	Sulphate of magnesia and phosphate of potash	4.70	16–21	77	4	5.19	15	46	2
10	Nitrate of lime, sulphate of magnesia, and phosphate of potash	9.29	16–24	90	5	3.95	12–16	80	5
11	Nitrate of lime, nitrate of potash, sulphate of magnesia, and phosphate of potash . .	6.71	16–27	84	5	4.35	16–17	69	5

* Details of some of the first trials with coal ashes, pit sand and green sand from New Jersey, have been given already in the Bussey Bulletin, **1.** 50 and **2.** 159.

*Loams mixed with Sand in the proportion 500 grammes loam to 700 grammes Sand.**

No. of jar.	The mixtures were watered with	PLAIN-FIELD LOAM. Crop harvested Feb. 20th, 1874.			APPLETON LOAM. Crop harvested Feb. 22d, 1874.			SALTONSTALL LOAM. Crop harvested Feb. 20th, 1874.			BERKSHIRE SAND alone. Crop harvested Feb. 17th, 1874.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Phosphate of soda	2.060	14	31	2.100	12-16	27	2.530	11-16	18	0.145	4-5¼	2
2	Phosphate of ammonia and nitrate of ammonia	2.550	15-16	9	2.265	11-15	23	2.615	10-16	18	0.125†	3-3¾	0
3	Nitrate of potash	1.415	9-13	9	1.345	11-14	3½ and flowers.	2.675	11-17	13	0.190†	10-11	2
4	Sulphate of lime and phosphate of potash	2.090	8-13½	19	1.525	8-17	6	2.530	11-17	39	0.190	4-6	1
5	Nitrate of ammonia	1.275	8-13	3 and many flowers.	0.920	6-13	14	2.645	10-15	7	0.090	6½-8	5
6	Sulphate of magnesia and phosphate of potash	1.965	11-12	6	2.175	11-13	19	2.195	11-15½	24	0.160	4½-5	2
7	Nitrate of lime	1.585	12-13	6	1.550	11-12	5¼	1.755†	11-16	1 and flowers.	0.450	7-9	4¼
8	Nitrate of lime and phosphate of potash	2.000	10-10½	15¼	1.590	10-15	14	3.530	16-17½	23	1.260	5-12	16
9	Sulphate of potash	1.285	11-14½	25	0.710	8-9	4¼	3.225	15½-16	18	0.175	3-6	1
10	Rain-water	1.230	9-13	13	0.705	9-10½	8	2.480	10-19	1 and flowers.	0.100†	3-3¾	0
11	Nitrate of potash and phosphate of potash	2.150	12-14	22	1.775	10-15	5	2.790†	17	33	0.620†	10-13	6
12	Sulphate of magnesia and nitrate of lime	1.390	11-12	9	0.939	8-11	2	2.835	13-17½	30	0.265†	7-9	4
13	Phosphate of potash	1.820	13-15	22	1.932	10-17	22	2.151	15	7 and flowers.	0.090	4-6	2
14	Nitrate of lime, chloride of potassium, phosphate of potash, and sulphate of magnesia	1.395	11-15½	15	1.190	8-13	8	2.625	13-15	25	0.820	7½-12	18

† Only two plants.

* For a table of results obtained from mixtures of Plain-field loam, and sand in varying proportions, see Vol. I. p. 262.

NOTE. — Analysis of substances mentioned in this table and the next gave the following results: Of *phosphoric acid* the air-dried Plain-field loam contained 0.26 per cent., Mr. Appleton's loam 0.14 per cent., Mr. Saltonstall's 0.23 per cent., the Dabney peat 0.23 per cent. Of *potash*, Plain-field loam contained 0.048 per cent., Mr. Appleton's 0.076, Mr. Saltonstall's 0.078 per cent., the Bussey peat 0.01 per cent., the Dabney peat 0.071 per cent., the micaceous Kaolin 0.53 per cent., and the pipe clay 0.61 per cent. Of *nitrogen*, the Plain-field earth contained 0.22 per cent., Mr. Appleton's 0.26 per cent., Mr. Saltonstall's 0.16 per cent., the Bussey peat 1.2 per cent., and the Dabney peat 0.84 per cent.

Peat and Clays mixed with Sand.

No. of Jar.	The mixtures were watered with	BUSSEY PEAT. Crop harvested Feb. 20th, 1874.			DABNEY PEAT. Crop harvested Feb. 20th, 1874.			"KAOLIN." Crop harvested Feb. 17th, 1874.			PIPE CLAY. Crop harvested Feb. 17th, 1874.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Phosphate of soda	2.400	11–17	34	1.680	8½–16	8	0.180	5½–7	2	0.070*	3½–8	0
2	Phosphate of ammonia and nitrate of ammonia	1.760	9–15	4 and flowers.	1.390*	14–16	11	0.715	8–10	8	0.535*	7–11	3
3	Nitrate of potash	2.455	9–22	28	1.675	16–19	10	0.360	8–10	8	0.220	5½–7	2
4	Sulphate of lime and phosphate of potash .	2.175	10–15	21	Lost.	Lost.	Lost.	0.100*	3–9	2¼	0.130	4–5	2¼
5	Nitrate of ammonia	2.680	12–19	37	1.310*	8–17	3	0.295*	7½–9½	4	0.185*	7–9	2¼
6	Sulphate of magnesia and phosphate of potash	2.760	13–14	9 and flowers.	1.645*	13½–15	11 and flowers.	0.115†	7	1½	0.150	5–6	2
7	Nitrate of lime	2.220	13	13	1.000*	10–15	10	0.135†	9½	1	0.305	6–7	4
8	Nitrate of lime and phosphate of potash .	2.680	13–16	24	1.590	5–16	6	1.285*	10½–11½	21	1.120*	11½–13	13
9	Sulphate of potash	2.045	7–16	6 and flowers.	1.740*	16–19	19	0.175*	6½–7	1	0.105*	7–7½	2¼
10	Rain-water	1.790	9½–12	10	0.975*	12–17	12	0.100*	5½–7	3½	0.060†	7	1
11	Nitrate of potash and phosphate of potash .	3.040	13–17	32	1.590*	13–15	5	1.630*	14–16	14	1.370	9½–16	30
12	Sulphate of magnesia and nitrate of lime .	2.040	12–17½	3 and flowers.	0.950†	14½	5 and flowers.	0.365	6–11	4	0.265	5–8	3
13	Phosphate of potash	2.190	12–14	14	1.410*	8½–12½	11 and flowers.	0.135*	6–10	3½	0.120	5–5½	1
14	Nitrate of lime, chloride of potassium, phosphate of potash, and sulphate of magnesia .	2.725	13–17	30	1.960*	17–20	21	0.630*	10–11	18	0.590	7–11	6

* Only 2 plants.   † Only 1 plant.

The trials with mixtures of peat and sand, and of sand and clay, as recorded in the tables, were simultaneous with the experiments upon loams and were in contrast with them. One of the peats which was obtained from the Bussey Farm (see vol. 1, page 135) contained 1.2% of nitrogen and 6.98% of ash ingredients. For the experiments, 250 grm. portions of it were mixed with 375 grm. portions of Berkshire sand. The other peat, from a pond-hole in Dabney woods, contained when air-dried 0.84% of nitrogen and 43.56% of ash. 300 grm. portions of this peat were mixed with 450 grm. portions of the Berkshire sand. It turned out, however, that the mixture of Dabney peat and sand was insufficient to fill the jars completely, and the plants suffered from a certain sogginess in this particular case. "Kaolin" is a trade name in Boston for a material, used as a kind of fire-clay, which consists of a mixture of fine clay and a multitude of very minute scales of mica. It seems to have been formed by the disintegration of a feldspathic and micaceous rock. For the experiments, 80 grm. portions of it were mixed with 1200 grm. portions of sand. The Pipe-clay was a compact fat clay, free from foreign matters, such as is sold as China clay in Boston, for purposes of luting. For the experiments, 45 grm. portions of it were mixed with 1300 grm. portions of Berkshire sand. For the experiments where Berkshire sand was used by itself, 1350 grms. of it were put in each jar.

For remarks upon the experiments with clay see beyond, page 309.

It will be noticed that in the series of experiments with pure loam an unusually large quantity of material (2 kilogrammes) was employed and that six seeds were sown instead of the usual number, three. For this particular set of experiments I had made a number of large glass jars, like beakers, only thick and strong. These jars were subsequently abandoned, inasmuch as they were found to be less convenient in practice than ordinary quart preserve jars and seemed to have no special merit.

The strength of the solutions employed in these experiments were as follows : Sulphate of Potash, Phosphate of Potash, Sulphate of Magnesia, Sulphate of Lime, and Chloride of Potassium 0.25 grm. each to one litre of water. Nitrate of Lime * 1 grm. to the litre, Nitrate of Potash 1.25 grm. to the litre, and Nitrate of Ammonia 0.125 grm. to the litre in most instances.

The most noteworthy results of these trials was the manifest

* It is noticeable of nitrate of lime even more than of any other of the nitrogenized solutions, that it imparts a peculiar green color to the plants that receive it, and tends to keep them young, *i. e.* it hinders the final ripening or maturing of the plant.

advantage gained by the plants from the nitrogen naturally con-
tained in the loams and peats. This point has been discussed at
some length in a special article in the first volume of the Bulletin
(see page 252). Indeed in the experiments with loam alone the
crops from jars numbered 6, watered with nitrate of ammonia,
seemed to show that there was little if any need of adding a nitro-
genous fertilizer; and some of the crops (Nos. 1 and 3, loam
alone) watered with the nitrates of potash and lime tended to cor-
roborate this view, when put in comparison with crops which had
received no nitrate. It seemed plain that no methodical results
could be hoped for until the soil-nitrogen had been got rid of.
Even in the experiments with the mixtures of loam and sand,
where the soil-nitrogen was of course greatly diluted, it frequently
appears as if no nitrogenous fertilizer·were needed, beside that
natural to the loam. Compare, for example, the experiments
with Plain-field loam.

The experiments seem to show that Mr. Appleton's loam needs
phosphoric acid and does not need potash, and that Mr. Salton-
stall's loam does not need phosphoric acid, though it may need
potash somewhat. As regards the Plain-field loam, the results are
somewhat conflicting; this loam responds freely to mixtures of
phosphoric acid, potash and nitrogen, though not to potash alone
in the manner that was to have been expected from its behavior
in the field.* It seemed to need phosphoric acid less than Mr.
Appleton's loam.

In respect to the experiments with peat, it is remarkable that in
several instances the plants were able to procure from the peat it-
self not only nitrogen, but enough phosphoric acid and potash to
bring fair crops to maturity, though the addition of active nitrogen
did good both by itself and when mixed with potassic and phos-
phatic fertilizers. In jar No. 5, Bussey peat which was watered
with nitrate of ammonia, the question suggests itself whether
ammonium may not possibly have fulfilled some function ordinari-
ly fulfilled by potassium. The case is somewhat different from
that of the mixture of Plain-field earth and sand Jar No. 2, which
was watered with a mixture of nitrate of ammonia and phosphate
of ammonia, for in this instance the ammonia compound may have
liberated potash from the soil which, as compared with the peat,
contained a considerable store of it.

In the Bussey peat the crops grew well and the experiment was

* Compare Bussey Bulletin, vol. 1., the several records of field experiments.

all that could be wished. The experiments with Dabney peat, on the other hand, were not successful and are hardly worth the publishing. It appeared, after the experiment was started, that the jars devoted to the Dabney peat were not sufficiently filled, so that in watering them it was not easy to avoid pouring an undue amount of liquid which kept the materials soggy and drowned out the plants. This difficulty arose from the peculiar texture of the peat. It might readily have been overcome in a new trial, if the experiment had been worth repeating.

The results obtained with the clays will be alluded to further on in another connection.

It was still manifest in all these experiments that the presence of the nitrogen natural to the soil interfered very materially with the assay. Efforts to avoid this difficulty were made by calcining the loams in an iron muffle,* and by growing crops either in the calcined earths directly or in mixtures of the calcined earth and sand. The calcined loams were moreover put in contrast with various natural sands. In all these later trials the experiments were greatly simplified by using a much smaller number of jars and watering with fewer solutions than before. There was of course grave reason to fear that the process of roasting might alter the chemical composition of the loams to such an extent that they could not properly be used after calcination. It might readily happen, for example, in roasting some loams, no matter how carefully or at how low a temperature the process was conducted, that the inert potassic or phosphatic compounds contained in the earth might be broken up and made more available as plant-food than they were originally, while in other loams a precisely contrary effect might be produced. But this was a matter which would be settled by the experiments, in so far as it bore upon the praticability of the assay.

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* A large muffle, one and a half feet long and eight inches wide, of very thin cast iron, was thrust into the upper door of the hot-air furnace used for warming the laboratory and made to rest upon an iron bar placed across the pot of the furnace just above the glowing anthracite with which the pot was filled. The muffle had no opening but its mouth. It was heated to low redness and the loam in it was stirred continually until the last traces of glimmering from the carbonized organic matter had ceased.

Calcined loams alone.

No. of jar.	Harvest, 17th-19th April, 1875. The jars were watered with	The crops from 1145 grms. CALCINED PLAIN-FIELD LOAM.			The crops from 1250 grms. CALCINED APPLETON LOAM.			The crops from 1120 grms. CALCINED SALTONSTALL LOAM.			The crops from 1170 grms. CALCINED BEAN-PLOT LOAM.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Sulphate of potash	0.260	5¼-9¼	1	0.250	4½-5	2	0.192	5-6¼	4	0.135	2¼-4¼	2
2	Phosphate of potash	0.190	5-6	3	0.140	5-5¼	1	0.180	4½-5½	4	0.190	4½-5¼	3
3	Nitrate of potash	4.820	15½-18½	38	6.600	17-24	74	4.380	16½-20½	54	3.410	12-19	33
4	Rain-water	0.195	5-6	5	0.193	4½-5¼	2¼	0.150	3½-5¼	3½	0.180	4-5	3
5	Nitrate of lime	4.510	18½-19	53	4.500	16-21¼	56	5.700	18-23	74	2.180	6-18¼	32
6	Phosphate of potash and nitrate of potash	9.520	21-22½	114	6.720	16½-23	99	5.230	19-25½	90	3.320	17½-20	58
7	Phosphate of potash and nitrate of lime*	8.160	13-23	60	4.900	16½-22½	66	5.055	16½-19½	48	4.250	16-21¼	70

* Used alternately.

Calcined loams mixed with Berkshire Sand.

No. of jar.	Harvest, 20th March, 1878. The jars were watered with	The crops from PLAIN-FIELD LOAM.			The crops from MR. SAL-TONSTALL'S LOAM.			The crops from BEAN-PLOT LOAM.			The crops from MR. BEATLEY'S LOAM.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Nitrate of potash	2.090	12-14	29	2.000	9-13	32	2.100	10-15	43	4.230	13-15	50
2	Nitrate of lime	1.835	6-10	16	1.500	7-12	20	3.300	8½-11	40	3.980	6-17	94

NOTE.— The brevity of these experiments is explained by the fact that they are partial repetitions of a more extended series (in sets of 5 jars each) which was damaged by a mouse just before the time of harvesting. Though the earlier experiments are unfit for publication, they had pointed, throughout the entire term of growth of the plants, to the same conclusions as those drawn from the trials with undiluted calcined loams. Hence it was thought best to repeat only the two most important terms, as above.

A comparative trial made with simple (uncalcined) loam from the Bean-plot gave the following results: Each jar contained 1026 grms. of the air-dried loam.

No. of jar.	Harvested April 17th, 1875. The loam was watered with	The crops.		
		Weighed grammes.	Grew to height in inches.	Had seeds.
1	Sulphate of potash	2.400	14½–17½	40
2	Phosphate of potash	2.950	17–20½	42
3	Nitrate of potash	3.710	16½–23	54
4	Rain-water	1.830	13½–19½	36
5	Nitrate of lime	2.845	14–17	34
6	Phosphate of potash and nitrate of potash .	5.800†	26½–30	71
7	Phosphate of potash and nitrate of lime * . .	7.850	25½–35½	132

* Used alternately.   † Only 2 plants.

The experiments with calcined loam alone went to show (compare Nos. 1, 3, and 5) that all the loams contained a good deal of phosphoric acid, of potash and of lime, and it is noticeable that the Bean-plot loam, which was taken in September, 1874, from an experimental plot, B 5 Beans,* which had been cropped continually during four years without manure, gave rather smaller crops than the rest. But there is a lack of emphasis in the difference between the results obtained from the original Plain-field loam and the Bean-plot loam which is in singular contrast with the difference exhibited by the field experiments.

Contrary to the previous experiments, the application of potash seems to be of some use to Mr. Appleton's loam, as well as in the case of the Plain-field earth, and the Bean-plot loam; though it did no good upon Mr. Saltonstall's loam. The loam from Mr. Saltonstall, from a poor old pasture, seemed best on the whole, as it had in the previous trials. It was noticeable that the crops upon all the calcined loams did very much better when watered with nitrate of lime than a number of sands similarly watered which were cultivated beside them. See p. 306.

In the hope that the differences between the loams might be brought out more clearly by employing them in a somewhat diluted state, new portions of several of them were calcined and mixed with Berkshire sand, in the proportion of 560 grammes of the calcined loam to 760 grms. of the sand, before proceeding to grow the crops. The results of the trial will be found in the lower table · on page 302. Taken in connection with all that had gone before,

* Bussey Bulletin, 1. 88.

they gave convincing evidence as to the limitations of the process. They show clearly enough that while this method of assay can readily distinguish a true garden soil, like the specimen from Mr. Beatley,* from the mediocre loams with which it was contrasted, it is incapable of making definite practical distinction between ordinary loams taken from fields and pastures here in Massachusetts. Indeed, as will be seen from the table, the loam from the " exhausted " Bean-plot gave rather better results than were obtained from the original Plain-field loam, and the loam from Mr. Saltonstall. This result may be due, of course, to changes in the composition of the loams brought about in the process of calcination, but the fact remains that the method of assay is incompetent to distinguish poor loams from those which are somewhat poorer. All this, quite beside the great practical difficulty of carrying out this kind of experiments, which require devotion of a peculiar order. As a general rule three months elapsed between the sowing and harvesting of my buckwheat crops, during which interval incessant care and watchfulness had to be exercised in order that the plants should be kept properly warm, properly cool, and sufficiently moist. The experiments would be ruined in case any carelessness should occur, in respect to either of these conditions, at any moment during the three months. I have been extremely fortunate throughout the experiments, both in the faithfulness of my helpers and in the absence of damage to the glass house from falling ice and snow. On only two occasions have any real disasters been met with: once in the beginning, when a spell of hot weather in early summer destroyed a house full of plants, and taught the lesson that work of this sort in a glass house must in this particular locality be limited to the cooler season ; and once, when a single mouse got into the house for one night in January at a time when more than a hundred plants were just ready to be harvested. As luck would have it, the animal ate some seeds here and others there in such manner that utter doubt and uncertainty was cast upon the whole collection of crops, and the three months' work had to be done over again in another year.

Of course, if the method of assay had succeeded, as was originally hoped, practical tests with it would naturally have been conducted in ordinary greenhouses where the usual care of the

* Analysis of the original (uncalcined) loam from Mr. Beatley showed that it contains 1.92% of potash (K_2O); 2.57% of lime (CaO) and 0.40% of phosphoric acid (P_2O_5).

house would have included that of the experimental plants, and the gardener would have had only the extra trouble of watering the plants with the chemical solutions.

I am aware that Ville has predicted conclusions * very unlike those at which I have arrived. I can only say'that I have hitherto been unable to find anything in Ville's published experiments which leads me in the least degree to change my opinion of the assay by sand culture. I deem the assay incompetent to give sharp, well-defined results, as between one loam and another ; and I am convinced that the results it does yield, in respect to loams are in no wise commensurate with the time, labor, and trouble they cost.

But though of little or no practical use for assaying cultivable earths, the process is valuable as a method of scientific research for testing sands, and some coarsely powdered rocks, or the like " inert" materials ; and as a means of detecting small or even minute quantities of available nitrogen. Indeed it has no small merit as a qualitative test to be used in certain cases. I have shown already in papers printed in 1874 and 1877 † that a just conception of the value of anthracite ashes, regarded as a source of plant-food, may be gained in this way ; that some part of the nitrogen ‡ in peat, loam, and roasted leathers is immediately available for plants, and that even coal slack may often contain enough ammonia to promote the growth of plants. Calcined loam and mixtures of calcined loam and inert sand afford admirable soils in which to test the question whether a given chemical compound containing nitrogen (an amid, for example) is capable of supplying nitrogenous food to plants. Probably the best way of testing such a substance, in case it is soluble in water, would be to put occasionally small-weighed quantities of it upon the soil and to use rain-water all the while for watering. So, too, there could hardly be a better way of illustrating the economy of the carniverous plants which have lately attracted so much attention than to transfer them to a calcined garden-soil and feed them there, for a considerable interval of time, with meat and egg, and insects, in contrast with other kinds of plant-food.

The following tables show the comparative value of several common sands : —

* "Chemical News," 1874, **30.** 288.
† Bussey Bulletin, **1.** 50 ; **2.** 159.
‡ Ibid. **1.** 62, 252, 398 ; **2.** 58, 72, 280.

Beach Sands and other inert materials.

No. of jar.	Harvested April 14th, 1875. The jars were watered with	The crops from 1400 grammes ESSEX SAND.			The crops from 1400 grammes PROVINCETOWN SAND.			The crops from 1320 grammes BERKSHIRE SAND.			The crops from 1000 grammes ANTHRACITE CINDERS.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Sulphate of potash	0.381	3½–9½	18	0.195	4½	3	0.195	4½–5	3	0.175	4–6	2
2	Phosphate of potash	0.440	5–11½	8	0.115	3½–4½	4	0.110	4–4½	2	0.105	3–4	8
3	Nitrate of potash	0.930	10–12½	3	1.530	13–15½	27	0.430	5½–9	8	1.520	13–16	36
4	Rain-water	0.441	7½–10	5	0.110	2½–4½	4	0.200	2½–4	0	0.210	5–6½	2
5	Nitrate of lime	1.533	10–10½	22	1.010	9	4	0.365	4–6	8	0.480	5½–8	1
6	Phosphate of potash and nitrate of potash*	1.805	6½–17	23	1.845	13–17	17	1.005	10–14½	8	0.540†	9½–14	13
7	Phosphate of potash and nitrate of lime*	2.210	9–21	34	2.350	18½–14	31	2.310	13–16½	20	4.180	11–22½	64

* Used alternately.   † Only 2 plants.

NOTE. — In connection with these trials 700 grammes of ground Saco Slate (such as was described and analyzed on page 8, Vol. II. of the Bulletin) were mixed with 225 grammes of Berkshire Sand in a jar like the rest; and after sowing the buckwheat this jar was placed in row No. 5 and watered with nitrate of lime. The crop weighed 0.480 gramme, the plants were 5½–8½ inches high, and there were 3½ seeds. Though a shade better than that from the Berkshire Sand, the crop was hardly better than that from the anthracite cinders. Possibly the fine powder of slate clogged the roots as clay seems to do.

Phosphatic Rocks.

No. of Jars.	Harvested Feb. 16th, 1878. The jars were watered with	1300 grms. Berkshire Sand and 50 grms. S. C. PHOSPHATIC ROCK. The crops			1250 grms. Berkshire Sand and 100 grms. BOG-IRON ORE. The crops			1340 grms. Berkshire Sand and 15 grms. BONE-ASH. The crops			1300 grms. Berkshire Sand and 50 grms. GREEN SAND. The crops		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Nitrate of potash	0.800	6¼–10¾	2	0.300†	7–8	¼	0.600	5–9	0	0.960	9–11	10
2	Nitrate of lime	0.250*	1½–3	0	0.350	2½–7	½	0.800	4½–6¼		1.710	7–8½	18

No. of Jars.		1340 grms. Berkshire Sand and 20 grms. SPENT BONE-BLACK.			1300 grms. Berkshire Sand and 50 grms. SPENT BONE-BLACK.			1340 grms. Berkshire Sand and 20 grms. FRESH BONE-BLACK.			1300 grms. Berkshire Sand and 50 grms. FRESH BONE-BLACK.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Nitrate of Potash	0.752	7–13	0	1.210†	11½–18	4	1.210*	9½–16	2	1.167	7–9½	1
2	Nitrate of lime	0.410*	7	0	0.900	4–7	0	0.915	5½–10	3	1.350	6½–13¾	9

* Only 1 plant.

† Only 2 plants.

As an example of the testing of a nitrogen compound (ossein) I would submit the following table of results obtained by growing plants in an intimate mixture of 560 grms. calcined loam from Mr. Beatley's garden, 760 grms. Berkshire sand, and 15 grms. of not particularly fine bone-meal.   These experiments were carried on simultaneously with those relating to roast leather (see vol. 2, p. 58) and are comparable with them, though they were made for another purpose, to test namely the power of plants of supporting phosphate of lime.

No. of jar.	Harvested April 20th, 1876. The jars were watered with	The crops.		
		Weighed grammes.	Grew to height in inches.	Had seeds.
1	Phosphate of potash	3.730	7½–14¾	60
2	Rain-water	2.450	9–11	25
3	Nitrate of potash	5.850	14–16½	38
4	Nitrate of lime	5.360	10–18½	69
5	Phosphate of potash and nitrate of lime . .	6.950	14–17	37

The sands employed in the experiments on p. 306 may be described as follows : —

The Essex sand is a fine soft micaceous variety of sea sand, from sheltered bays behind Cape Ann, Mass., such as is sold by grocers in Boston as " washing-sand " for sanding floors and for scouring wood-work.   It contains flakes of mussel-shells besides numberless scales of mica, and has evidently been deposited from still waters.   Before using this sand I washed it thoroughly, by stirring it up repeatedly with successive portions of rain-water in order to float off any dust that might have adhered to it.   It was afterwards dried and weighed.   Analysis * showed that the Essex sand contained a good deal of potash (2.384%), and 0.051% of phosphoric acid.   The experiments of the table, on the other hand, show that this sand contained an appreciable amount of nitrogen available as plant-food, much potash and a noteworthy amount of phosphoric acid.

The Provincetown sand, from a dune at the end of Cape Cod, evidently contained no nitrogen but a good deal of phosphoric acid and potash.   Analysis * had shown that this sand contained 0.613% of potash and 0.05% of phosphoric acid.

The Berkshire sand * showed no nitrogen and the usual small quantities of phosphoric acid and potash.

* Bussey Bulletin, 2. 11.

The anthracite cinders were half burned bits of anthracite which had fallen through the grate bars of a furnace fire. Each bit was freed from ashes and was coarsely powdered for the experiment. It was plain from the experiments that while the cinders contained no nitrogen available for the plants, they could supply an appreciable quantity of phosphoric acid and some potash also. It may here be repeated that a certain small proportion of nitrogen detected in coal ashes in some of my earlier experiments was afterwards proved to have come from coal slack, that is to say particles of unburned coal which had fallen through the bars of a shallow furnace.*

Since all the jars numbered 7 in this series of experiments gave better crops than those numbered 6, it appeared that lime was a useful addition to the sands. It is noteworthy furthermore that while the plants grew fairly well in these sands proper, as is plainly evidenced by the Nos. 7 which had an abundant supply of food, they failed to prosper in sand with which clays had been mixed.

The table relating to clays which has been printed on page 298, hardly conveys a just impression of the poverty of the crops. To do that, the miserable, sickly, crippled plants would have to be exhibited as they appeared in reality. To all appearance, the fine particles of clay actually clogged the pores of the plant roots and prevented the healthy development of the plants. So, too, in connection with the series of experiments reported on page 256 of vol. 1, there was another jar that contained 250 grammes of pipe clay and 230 grms. of Bussey peat. But only one plant grew in it, and that to a height of but six inches. It died more than a month before the crops in the other jars were harvested and weighed only 0.08 grm. It had neither seed nor flower. In earlier experiments with mixtures of sand and clay the hurtful influence of the latter was still more apparent, as will appear from the following tables : —

* See Bussey Bulletin, **1.** 401.   .

Mixtures of Clay and Sand.

No. of jar.	BUCKWHEAT. The jar was watered with	Each jar contained 1200 grms. Berkshire Sand and 150 grms. Clay. Crop harvested May 22d, 1873.			Each jar contained 1250 grms. Berkshire Sand and 100 grms. clay. Crop harvested May 22d, 1873.			Each jar contained 1300 grms. Berkshire Sand and 50 grms. clay. Crop harvested May 22d, 1873.		
		Weighed grammes.	Height in inches.	Had seeds.	Weighed grammes.	Height in inches.	Had seeds.	Weighed grammes.	Height in inches.	Had seeds.
1	Rain-water				0.090	1¼-4	0	0.100	5-7	3
2	Nitrate of ammonia	0.080	3-7¼	1	0.165	6-7	6	0.265	7-9	3
3	Phosphate of ammonia and nitrate of ammonia	0.090	5¼-6¼	0	0.190*	7-9		0.400	9-11	8
4	Nitrate of potash	0.095	4-5¼	1½	0.125*	6-8½	3¼	0.305	10	3 & flow's.
5	Nitrate of potash and phosphate of potash	0.555		7½	1.190	13-16	13	0.930	13-15	10

* Only 2 plants.

NOTE.—Three buckwheat seeds were planted in each jar; but, as regards the first series with 150 grms. clay, only two miserable plants were harvested in each instance, excepting jar No. 5. In jar No. 1 all the plants died soon after their first appearance.

Some mixtures of Sand and Clay with Maize as the crop.

No. of jar.	MAIZE.	Weighed grammes.	Height in inches.	Had seeds.	Weighed grammes.	Height in inches.	Had seeds.	Weighed grammes.	Height in inches.	Had seeds.
1	Rain-water		3-8½			9			8-11	
2	Nitrate of ammonia		11			8-16			15-17	
3	Phosphate of ammonia and nitrate of ammonia		6-12			14			15-16	
4	Nitrate of potash		15-17			17-18			20-21	
5	Nitrate of potash and phosphate of potash		16-22			20-21			25	

NOTE.—Two kernels of common yellow maize were sown in each jar, and the plants grew to the heights recorded in the tables during the two months allotted to the experiment. But with the exception of the jars numbered 6, whose crops were healthy and growing vigorously when the experiment was closed, the plants were thin and miserable and not worth the trouble of weighing. Both with the Buckwheat and the Maize the plants were best in the mixtures which contained the most sand and the least clay. There was a regular gradation in the appearance of the plants down to those jars which contained the least sand and the most clay.

In a yet earlier set of experiments, buckwheat was sown in a mixture of 1500 grms. Berkshire sand and 500 grms. of the pipe clay. But this proportion of clay was manifestly far too large. Eleven large jars were charged with the mixtures, six seeds were sown in each jar, and the plants were watered with chemicals such as were used for the experiments reported on page 54 of Vol. I.; but only a few of the plants grew to a greater height than 3 or 4 inches, and they were all miserable failures. In this case the soil seemed to be too compact.

These results illustrate the great importance of keeping in view the mechanical improvement of clay soils in all processes of fertilizing and tilling them; — a point upon which much light has recently been thrown by the writings of Prof. Hilgard.*

There is no need of discussing at any great length the arguments upon which the use of one and another of my chemical solutions were based. As the work proceeded the tendency has been to simplify the tests, and I would now use a much smaller number of chemicals than I dared restrict myself to at first. The following example will illustrate well enough the general line of argument. In 1873 experiments were tried with six solutions, namely :

1. Phosphate of Potash, to show if there was any nitrogen in the soil, available as plant-food. In case the soil was known to contain nitrogen, sulphate of potash would be used instead of the phosphate of potash, and the purpose of the jar would then be to exhibit the phosphoric acid in the soil, in comparison with jar No. 2   •

2. Nitrate of Potash : To exhibit the presence of phosphoric acid in the soil; to show if any advantage is gained by adding potash or available nitrogen, and to contrast with jar No. 4.

3. Rain-water : To contrast with the other jars, and particularly with No. 1.

4. Nitrate of Lime : To show potash, phosphoric acid and the need of lime, and to contrast with jar No. 2.

5. Nitrate of Potash and Phosphate of Potash : To see if the soil needs lime.

6. Nitrate of Lime and Phosphate of Potash : As the only " complete " mixture.

It was held that the rain-water contained, beside some lime, enough chlorine and sulphuric acid for all practical purposes. In case magnesia or other essential element of plant-food were absent from a soil, the fact would be indicated by the failure of the plants in jar No. 6, and new experiments could then be undertaken to meet that special case. The chief defect in so limited a number of solutions as the foregoing is that we cannot get from them that mass of corroborative proof which is naturally afforded by a larger number of tests. When a single solution indicates some fact we are not sure but that this indication may be accidental, but when the results from two or three different solutions all point to one conclusion we are quite ready to accept it.

* " American Journal of Science," 1879, **17.** 205.

The results with sand, and those with coal ashes *. also, go to show that the process would be applicable for testing some kinds of coarsely powdered rocks, such as granite * for example, but with single minerals the case is different. For testing a mineral (phosphate rock for example,) it is not sufficient to mix it with an inert sand, since the mechanical texture of the sand is apt to be very different from that of the powdered mineral, and since the sand may not contain enough of the subordinate kinds of plant-food to meet the requirements of the case. The results recorded in the lower table on page 000, show indeed that the plants got some phosphoric acid from the phosphate-rock, the bone-black, and the green sand of the experiments, but it was plain that the crops did not derive nearly so much benefit from these materials as they might have done under more favorable conditions. Instead of inert sand there is needed a more generous material, such for example as a calcined loam of known value which should contain all the inorganic elements of plant-food. But since experience teaches that it is not easy to distinguish one such loam from another, there is little reason for hoping that the value of the phosphate-rock would be properly exhibited in case it were admixed with the loam. Instead of pursuing this line of inquiry, I sought rather to find a sand which would meet the requirements of the case, and in view of the importance of having some organic matter in the soil, to help dissolve the phosphate or other mineral, I incorporated the powder to be tested with a mixture of inert sand and peat that had been thoroughly leached first with hot muriatic acid and then with rain-water until the acid had all been removed. But the experiments made in this way, with phosphate-rock, mica-clippings, bone-black, and bog-iron ore, were not satisfactory. The soils thus constituted were cold and sour and soggy; the buckwheat plants that stood in them were sickly and distressed, and it was plain that no just conclusions could be drawn from results obtained under such conditions. Possibly, the free humic acid which must have resulted from the action of the muriatic acid in removing bases from the peat, was hurtful to the plants? If I were to repeat the trials, I would seek for a natural peat that contained very small proportions of nitrogen and ash ingredients, and would employ it admixed with sand as the normal earth in which to test a powdered mineral.

* Bussey Bulletin, 1. 50; 2. 159.

For the sake of completeness the experiments with leached peat, sand, and minerals are here recorded, though the results are of little value. The phosphate-rock was in the state of fine powder and so· was the iron ore. The spent bone-black was a coarse powder, such as is found in commerce. The mica was clipped fine with scissors.

Mixtures of Sand, Leached Peat, and Minerals.

No. of jar.	The jars were watered with	Each jar contained 900 grms. Berkshire Sand, 100 grms. leached peat, and 50 grms. Phosphate-rock.† Crop harvested March 9, 1878.			Each jar contained 900 grms. Berkshire Sand, 100 grms. leached peat, and 100 grms. Bog-iron ore. Crop harvested March 9, 1878.			Each jar contained 900 grms. Berkshire Sand, 100 grms. leached peat, and 20 grms. spent Bone-black. Crop harvested March 9, 1878.			Each jar contained 1000 grms. Berkshire Sand, 75 grms. leached peat, and 50 grms. Mica. Crop harvested March 9, 1878.		
		Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.	Weig'd grms.	H'ght in inches.	Had seeds.
1	Sulphate of potash	0.648	9½–10	4	0.180 ‡	6–6½	3	0.550 ‡	8–13	6	0.175	3–4½	2
2	Rain-water	0.150	4½–7	0	0.190	3–3½	0	0.500 ‡	4–6	0	0.245 ‡	6–6½	0
3	Nitrate of potash	1.760	10½–13	2	0.315	6½–7	1	0.610	4½–7½	0	0.170	2½–4½	0
4	Nitrate of lime	.	.	.	.	.	.	.	.	.	0.210 *	2½–5	0
5	Rain-water *	.	.	.	.	.	.	.	.	.	.	.	.

* In jar No. 5 ten grms. of bone-ash were placed at the time of mixing the materials.   † Containing 29 per cent. P_2O_6.   ‡ Only 2 plants.

Note on the use of Rain-Water for experiments in growing plants.

In the beginning, that is to say before any of the experiments above recorded had been made, I had many doubts as to the practicability of using rain-water for the proposed assay; but these doubts were quickly dissipated by the results of the experiments. The results of every trial have shown most conclusively that the rain-water was extremely well-fitted for the use to which it was put, and I believe that in general pure rain-water, such as I used (compare page 295), will be found better than ordinary distilled water for experiments like the foregoing. The constancy of the composition of rain-water, as taken from the great cistern which supplied me, is one very important consideration, since it relieves the experimenter from the risk of variations such as might readily arise through accidents, mistakes, or carelessness in the preparation of distilled water during the long terms of the experiments. Boussingault showed long ago that in preparing distilled water in the ordinary way we concentrate in the distillate the ammonia which was previously disseminated throughout the entire bulk of water taken for the operation, whence it may readily happen, in case the amount of distillate prepared is small, that the " purified " water will be contaminated with a hurtful amount of ammonia. For the sake of the comparison, I have myself sometimes grown plants in several pairs of pots of sand, with and without the addition of inorganic chemicals, *i. e.* ash ingredients, and have watered one set of the pots with rain-water and the other with distilled water, and have found that as a rule it was from the distilled water rather than from the rain-water that the plants tended to get some traces of nitrogenous food. When the distilled water was carefully prepared, with the express view of excluding ammonia, it yielded to the plants no more nitrogen than the rain-water, that is to say it was as good as rain-water for my purposes; but unless these pains had been taken to exclude ammonia, the distilled water, though such as would be used without hesitancy in the laboratory for most purposes, was no better than the rain-water but on the whole rather worse. Those chemists who are most familiar with the preparation of water free from ammonia, such as I have described in the " American Journal of Science," 1876, (3.) **12.** 182 *note*, will most keenly appreciate the advantage of being able to use rain-water in experiments with plants.

In order to gain some idea of the character of the rain-water used in these experiments, I have had it tested from time to time with Nessler's reagent, with the result that the water as taken from the cistern contains from 0.00048 to 0.00053 grm. of free ammonia (NH_3) to the litre, and 0.00006 to 0.00008 grm. to the litre of the albuminoid ammonia of Wanklyn. Most commonly the tests gave 0.0005 grm. of free ammonia. No differences in the amount of ammonia were noticed on testing the cistern-water during or after heavy rains. But it appeared that the plants really received less ammonia from the rain-water than the above

figures would indicate, for it was found that when water taken from the cistern was left to stand in open vessels in the greenhouse it lost some of its ammonia. Thus a sample left three weeks in a tall open glass jar (from 25th April to 13th May) contained 0.0005 grm. NH_3 to the litre at the beginning and 0.0003 grm. at the close of the trial. Another sample left standing in an open jar from 21st May to 7th June exhibited a precisely similar diminution, while a companion sample which stood in a closed bottle during this interval contained 0.0005 grm. NH_4 at the close as well as at the beginning of the trial. A half litre sample left standing in a wide-mouthed jar from 18th June to 28th July showed only a trace of ammonia when tested with Nessler's reagent, though the water had been found to contain 0.0005 grm. NH_3 to the litre at first. A companion sample kept in a closed bottle beside the other during the same time was found to contain precisely as much ammonia at the end of the trial as at the beginning. Another sample of the cistern-water which had stood in an open vessel from 18th June to 6th August contained only 0.00002 grm. NH_3 to the litre at the last-named date. A slight loss of ammonia from open vessels was invariably observed excepting a single instance, where a sample of the cistern-water was left to stand in the greenhouse in a tall open jar for twenty-four hours on the 23rd April, 0.00048 grm. NH_3 to the litre being found both at the beginning and at the end; but when this sample of water had stood forty-eight hours, the test showed only 0.00044 grm. NH_3. At the same time a closed bottle of the water which had stood for forty-eight hours showed 0.0005 grm. NH_3 to the litre. Furthermore a sample of the cistern-water kept in a closed bottle from 18th June to 5th Oct., 1875, was found to contain precisely as much ammonia at the end as at the beginning. For the sake of comparison, enough pure chloride of ammonium to amount to 0.0005 grm. to the litre was dissolved in pure distilled water and the solution was left to stand in an open wide-mouthed jar from the 16th August to 5th October, 1875, pure water being occasionally added to the jar to compensate partially for the loss by evaporation. When tested Oct. 5, the solution contained only 0.00018 grm. NH_3 to the litre; i. e. the loss of ammonia amounted to 0.0003 grm.

I was inclined to attribute this diminution of ammonia in the rain-water mainly to evaporation or perhaps to exhalation, in view of the constancy of the proportion of ammonia in the water of the cool underground cistern. Some of the ammonia might of course be changed to nitrites and nitrates; and this point was tested in the single experiment, where the water stood from 18th June to 6th August, 1875. By means of the aluminum-soda method (as described by Wanklyn in his "Water-Analysis," edition of 1874) there was found in the sample of water which had stood in the open vessel as much nitrite and nitrate as would amount to 0.0002 grm. NH_3 to the litre, while in the water which had stood in the

closed bottle there was found as much nitrite and nitrate as amounted to 0.0003 grm. NH_3 to the litre.

I had prepared to study this question of the loss of ammonia from water in some detail, when the publication of Houzeau's experiments upon the subject (Comptes Rendus, 1876, **83**. 525) induced me to withdraw and leave the field to him. It is noticeable that Houzeau's results differ from mine in that he observed a diminution in the amount of ammonia in well-water kept, in the light, in closed bottles; while no loss occurred in my samples of bottled rain-water. Manifestly different causes were at work in H.'s experiments and in mine.

Besides ammonia, my cistern-water naturally contained traces of nitrites and nitrates; but, as the growth of the crops showed, the amount of these ingredients added to that of the ammonia was not large enough taken altogether to interfere with the experiments or impair the accuracy of their results. All my experience goes to show that rain-water is well suited for the purposes of the proposed assay and for other kinds of experiments upon the growth of plants.

With respect to the presence of organisms in the cistern-water, I find fewer of them there than in most of the sands and loams employed in my experiments. After the crops were harvested, I examined with the microscope the soils taken from many of the jars with the result that while in the sea sands and natural loams there was an abundance of small green algæ (visible even to the naked eye), some diatoms and a few creatures of a higher order, the calcined loams and anthracite cinders were comparatively free from such inhabitants. There were some green algæ, it is true, in most of the jars, but I found nothing else in the calcined loams, and it seemed plain that most of the organisms found in the sands were there originally when the sand was placed in the jars. Even the jars which contained the New Jersey green sand (which is a mined or quarried product) were free from visible organisms.

At the time of these examinations I filtered a quantity of rain-water from the cistern and examined the residue with the microscope, but I found nothing but a few round algæ and a few opaque or black round bodies of unknown character.

January, 1880.

No. 28. — *A Special Instance of the Resistance of Clover-Seeds to Water*.   By F. H. STORER, Professor of Agricultural Chemistry.

THE following observation seems worthy of being put upon record, as corroborative of others relating to the same subject which have been published, and as illustrating anew a matter which is of no small importance to farmers.

Not far from the Bussey Institution there is a sheet of water, some 56 acres in area, known as Jamaica Pond, which is practically a great basin or reservoir from which water is pumped, by steam power, into an aqueduct which supplies a small part of the city of Boston.   This pond is ordinarily kept full by the flowing in of rain-water from the surface of the adjacent country, and by the soaking in of ground-water from the surrounding soil.   In the summer of 1880 there was a long-continued drought of such severity that during several months the amount of water flowing into the pond from the natural sources of supply was much less than the quantity pumped out from the pond to feed the aqueduct. The surface of the pond was thus drawn down to an extremely low level ; a broad, bare, somewhat gravelly margin was left upon the shore, and the proprietors of the aqueduct were finally forced to procure a supply of water from another corporation in order to supply a part, or perhaps the whole, of their customers.   As soon as the term of drought was broken, the pumping went on again and was continued so constantly that the natural sources of supply could barely make good the water which was expended.   They were incompetent to fill up the pond completely to the point at which it had stood before the drought began.   In the year 1881 there was still left a tolerably broad marginal beach around the pond.   But in spite of its recent recovery from the water the gravel of this beach was not bare.   Early in July, 1881, I noticed that the shore was thickly beset with white clover (*Trifolium repens*) in blossom, and on requesting my colleague, Mr. C. E. Faxon, to view the premises with a botanist's eye, he reported that there was not only an abundance of white clover on the beach, but a noticeable number of plants of yellow clover also ; that is to say the '' hop clover '' (*T..agrarium*).   Clover-seeds had evidently been sunk in previous years near the shores of the pond, when the water was

at its normal height, and had now germinated when opportunity offered. The observation is the more emphatic, since the receding of the pond-water in 1880 was a very exceptional occurrence which had excited much comment in the neighborhood, and all the circumstances attending the appearance of the clover-plants pointed directly to the presence of a store of seeds which must have been laid down when the place was covered with water.

The foregoing instance of the preservation of clover-seed under water is manifestly similar to those reported by Delius * in Germany, and by Professor S. W. Johnson † of New Haven. The German example was that of a pond which was laid dry at intervals and sown with summer grain. One spring a great quantity of white clover and Swedish clover sprang up, much thicker it is said than would have been the case if the seed had been sown purposely, and the bed of the pond was covered with clover-plants. In the Connecticut case, cited by Prof. Johnson, a farmer put upon a worn-out pasture some mud taken from a cove on the Connecticut River, where " the mud was under water the year round," and was surprised to see white clover come up quickly in the pasture where the mud had been strewn. As Professor Johnson has remarked, in describing the foregoing example, Nobbe and Haenlein ‡ have tried methodical experiments upon the power of clover and a variety of other seeds to resist the action of the water. On placing a number of white-clover-seeds in contact with water at a temperature of 65° to 68° F., under circumstances favorable for the germination of the seeds, they found at the end of ten days that 64 seeds remained hard and "lifeless"; but, as time went on, 8 of these residuary seeds softened and sprouted at intervals ranging from the 12th to the 247th day after they had been placed in the water; 8 of the seeds decayed and the other 48 remained hard after 292 days soaking. In experiments on red clover ($T.$ $pratense$), twice repeated, 30 and 10 seeds, respectively, out of a thousand did not swell in 156 days, when kept moist, at 65° to 70° F. Of the other 970 and 990 seeds, 919 and 927, respectively, swelled on the first day, and the others at intervals ranging with tolerable uniformity from the 3rd to the 156th day. In two

* Cited by Nobbe in his " Handbuch der Samenkunde," Berlin, 1876, p. 114 *note.*

† " Report Connecticut Agricultural Experiment Station for 1879," p. 123.

‡ " Die landwirthschaftlichen Versuchs-Stationen," 1877, **20.** 71; and Nobbe in his " Handbuch der Samenkunde," p. 112.

experiments each with a thousand seeds of the kidney-vetch (*Anthyllis vulneraria*) 842 and 962 swelled in water in the course of three days, and 126 and 36, respectively, at intervals between the 5th and the 262nd day. In the first trial 10 of the seeds swelled on the 262nd day, and two on the 138th. It was noteworthy in these trials that the capacity of the seeds to imbibe water did not necessarily indicate that the seeds would germinate. In the first trial with the vetch-seeds, for example, 84% of the seeds were swollen on the 3rd day, while only 8% of the seeds from which this sample was taken had been found capable of germinating.

In a trial with Swedish clover (*T. hybridum*), of 35 seeds that remained hard after 10 days' soaking, 7 swelled at intervals ranging from the 2nd to the 184th day thereafter. One seed rotted on the 173rd day, while the remaining 27 seeds were still hard and unswollen on the 292nd day. Analogous results were obtained also with seeds of lucerne, and with a variety of other seeds, notably those of weeds.

It is evident that facts like these go far to explain the opinion held by some farmers in New England that the use of pond-mud as a fertilizer is to be deprecated, " because the mud tends to bring in sorrel and other weeds "; for if clover-seeds can thus resist the leaching and decomposing action of water, it is probable that there are other kinds of seeds equally resistant that may be preserved under circumstances similar to those just now indicated, and finally spring up to annoy the farmer in places where they would naturally be least expected. This view of the matter has quite recently been elucidated and supported most fully by a second research of Haenlein,* who tested the seeds of 31 different kinds of weeds and wild flowers. In these trials it was found that some kinds of weed-seeds were still capable of germinating, and did in fact germinate after they had been kept continually moist and warm in the air for more than three years; while the seeds of other kinds wholly failed to germinate during this time, under conditions which were to all appearance favorable for germination. The most extraordinary differences were noticed as to the times of germination, not only as regards different kinds of seed, but in respect to different individual seeds taken from one and the same sample. Thus out of 400 seeds of ordinary pig-weed or lambs-quarters (*Chenopodium*

* "Die landwirthschaftlichen Versuchs-Stationen," 1880, 25. 465. Compare this Bulletin, p. 291.

album), 2 germinated on the 6th day, and 2, 3, 2, and 1 at intervals between the 6th and the 145th, when 19 germinated. 53 germinated on the 351st day, and 27 on the 519th, then 2 on the 874th, 3 on the 1082nd, and 3 on the 1173rd day, while 283 of the seeds still remained inert at the time last mentioned.

Out of 400 seeds of the common plantain (*Plantago major*), one single seed germinated on the 1173rd day, while none of the others had either germinated or decayed. The seed which did germinate yielded a normal, vigorous plant which appeared to have lost nothing by the delay.

Out of 400 seeds of St. John's wort (*Hypericum perforatum*), one germinated on the 7th day, 2 on the 10th, and several others at intervals up to the 72nd day, after which none germinated until one on the 714th, 3 on the 874th, and one on the 1082nd days; in all $14\frac{1}{2}$% to this date.

Of 400 seeds of shepherd's purse (*Capsella bursa pastoris*), 3 germinated on the 5th and 3 on the 7th days, then none until the 145th day when 4 germinated. Seven seeds germinated on the 1173rd day, — in all $18\frac{3}{4}$% to that date.

The fact of clover-seeds remaining uninjured in water is manifestly of the same order as their power of resisting the digestive juices of animals, that is to say of passing through their intestines without having the germinative power impaired. It has often been observed that the dung of neat cattle, and of horses, which have been fed upon clover-hay will afford an abundant crop of clover in fields previously free from this plant, especially when care has been taken to distribute the dung evenly upon the land.

The widely spread popular practice of treating the seeds of certain leguminous flowering plants with boiling water, as a preliminary to sowing the seeds, which prevail among gardeners and amateurs in this country as well as in Europe,[*] may evidently be classed among devices for overcoming the resistance of the seeds to imbibition. The seeds to which this method is applied are, according to the usual practice, thrown into boiling water and allowed to cool in and with the water. They are then sown in the earth. The very fact that some kinds of seeds can withstand such severe treatment as this is emphatic evidence of their power of resisting

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[*] Compare Knop's "Agricultur-Chemie," I. 526. Spallanzani and Herschel dwelt upon the fact long along, as stated by Lyell in his "Principles of Geology," 8th edit., London, 1850, p. 599.

outside influences; for, as Knop has already suggested, if the seeds were not encased in armor the boiling water would quickly coagulate the albumen and destroy the life of the seed. Doubtless the boiling water would destroy the seeds if they were thrown into it after being swollen in water at the ordinary temperature of the air.

It may be here said that Nobbe tried the effect of soaking clover-seeds in alcohol, and in ether, for the purpose of removing any waxy or resinous covering which might be supposed to resist water, but he found that the germination of the seeds was not accelerated by the treatment with these solvents; whence he argued that the resisting power probably depends on the anatomical structure of the outer covering of the seeds. In view of the "opening" power of boiling water, however, it may perhaps still be asked whether some weak alkaline solvent might not perhaps hasten the softening and the germination of the seeds. It is conceivable, indeed, — though for various reasons it is not very probable, — that the well-known practical utility of dressings of wood-ashes and of lime as applied to clover-fields may depend in some part on their facilitating the germination of dormant seeds. The common remark, that wood-ashes and lime bring in white clover, might seem to point to such a conclusion. One difficulty with the suggestion is that other potassic manures that are not alkaline, such as kelp and rock-weed, and the neutral potash-salts also, serve about as well as ashes. It might be urged also that, if the action of alkaline solutions favors the germination of clover-seeds, the biliary juices of animals should likewise do so. To which it may be replied that for aught that is known this may really be the case. That is to say, it is not unlikely that the germination of clover may actually be facilitated by the passage of the seeds through the intestines of animals, and that in the instances above noted, where the dung of animals has brought in clover, the unlocking of the seeds may perhaps have been one cause of the appearance of the plants in such abundance.

Another practical point worthy of being studied is the belief held by some New England farmers that white-clover-seeds germinate best when they have never been separated from their chaff, but are sown with the husks still upon them.

Beside clover, the endurance of the germinative power of charlock-seeds (*Sinapis arvensis*), when buried in the soil, has been repeatedly insisted upon by practical men, — with much jus-

tice, as I am satisfied by facts which have fallen under my own observation. Indeed, I can report some tolerably definite experience upon this point also. In the year 1870, when the Bussey Institution was organized, the " Plain-field " upon which the school-building now stands carried a crop of rye, as it undoubtedly had done at intervals in previous terms of years, since rye in alternation with grass was a favorite crop upon the farm ; and the field had doubtless received meanwhile dressings of dung that contained charlock-seeds. At all events the soil of this field, when it fell to my charge, was — like the rest of the farm — full of charlock-seeds. During the years 1871–74 a good part of the Plain-field was covered with experimental plots of which only those devoted to barley * were favorable for the growth of charlock. Upon the barley plots this weed grew in abundance. In the autumn of 1875 the whole field was laid down to grass, with artificial fertilizers, but without any addition of stable-manure or compost. During the first year or two after the seeding, that is to say in 1876 and 1877, a good deal of charlock appeared among the grass plants, but they were persistently pulled up and carried away before their seeds could ripen, and finally when the sod became thick and firm with June grass it appeared that the charlock had been effectually " smothered." But although charlock-plants no longer appear among the grass of this field it is none the less true that the soil is still full of vigorous seeds of the pest. It is only necessary to break through the sod and to turn up some of the soil in order to have an abundant crop of charlock spring up in the course of a few days or weeks. This experience has been had anew each year on the occasion of planting trees and shrubs in different parts of the field and has been noted with no little interest. I have myself no doubt that charlock-seeds which were buried in the soil as long ago as 1875, and many that were probably shed at a much earlier period, are now (1881) perfectly vigorous and ready to avail themselves of the first chance to germinate which is offered when the soil is stirred. I am well aware that the time which has elapsed since this particular observation began is, comparatively speaking, short and I have no doubt that many farmers can recall from their own experience instances where an abundance of charlock has sprung up on their fields after it had been smothered by grass during a much longer term of years. But I suppose that in such

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* Compare the first volume of the Bussey Bulletin.

cases the special point of the germination of the charlock-seeds has rarely been observed so attentively, year after year, as it has been in the present instance; and it is altogether unusual for a cultivated field to be so long deprived of barn-yard manure as this one has been. The observation seems worthy of record, because it has been somewhat carefully made under exceptional conditions and because it tends to support the ordinary impression of farmers that charlock-seeds can retain their vitality for long periods when buried in the earth. It is of course very difficult to prove a point like this, but it is none the less desirable that whatever of truth there may be in the popular impression shall be exemplified and placed as far as possible beyond doubt or dispute. To this end such evidence as can be collected should be put upon record and taken for what it is worth. It is important at all events that the opinion now prevailing among naturalists, that few seeds can long retain their vitality should be qualified in so far as may be necessary to bring it into harmony with all the facts of practical experience. When the best possible conditions for preserving each kind of seeds shall have been discovered, the reasons of the present diversity of opinion as to the endurance of the germinative power will doubtless be made plainer than they are now.

It would be interesting to continue these observations upon the Plain-field for a long series of years, since it would probably not be easy to find so favorable an opportunity elsewhere.

As good examples among the numerous instances that have been recorded of the long-continued endurance of seeds I would refer to President Timothy Dwight's * description of instances of mustard, &c. growing after many years, when old fields are broken up; to Thoreau's † observations of strange plants that grew in the cellar of a very old house at Concord soon after the destruction of the house; and to H. von Mohl's ‡ remarks on plants growing in new railway cuttings.

October, 1881.

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* In his "Travels in New England and New York." New Haven, 1821, **2.** pp. 440–442.

† "Abstracts of Returns of the Agricultural Societies of Massachusetts," 1860, p. 22.

‡ Hoffmann's "Jahresbericht der Agricultur-Chemie," 1866, **9.** pp. 164, 165.

No. 29. — *Cherry-stones eaten by the Domestic Pigeon.*
By F. H. STORER, Professor of Agricultural Chemistry.

IN August, 1881, I noticed that a pair of pigeons belonging to the neighborhood began to visit the roof of the large stone building of the Bussey Institution very frequently, and supposing that they intended to build a nest there I kept an eye on their movements with the intention of preventing them from so doing, for the building had previously happily been free from the visits of such birds. It soon appeared, however, that the pigeons had no intention of nesting on the building, and that they had simply fallen into a habit of resting quietly several hours each day in one particular corner of the roof which was sheltered from the sun's rays, and in this habit they persisted during August and September and the earlier part of October, and indeed in some measure for a much longer period, as will appear in the sequel.

Early in October I noticed that a considerable quantity of dung had collected on the roof beneath the roosting-place of the birds, and in giving directions for its removal I was surprised to see that it consisted almost wholly of broken cherry-stones. At first sight, indeed, the dung seemed to be mere gravel and it was so described by the laborer employed to remove it, but on closer inspection it appeared that the supposed gravel really consisted of fragments of cherry-stones of all conceivable shapes and sizes from the magnitude of one third a mazzard stone down to the merest dust. At the time of this first collection there was something like two quarts of the broken stones which had been passed by the two pigeons in the course of little more than two months, and that during the intervals of time which they had spent at this corner of the roof which was not their proper home and had served them only as an occasional resting-place. In all this mass of fragments I could detect only two whole unbroken cherry-stones, one large enough to have been a mazzard and the other as small as a choke-cherry stone. There was one fragment which was plainly half a mazzard stone, but most of the pieces were no larger than one quarter or one third of a stone, as has been said. Four or five quartz pebbles were found also among the dung, each of them as large as a mazzard-cherry stone.

From the lateness of the season at which some of the dung had

evidently been voided and from the general appearance of the frag-
ments I supposed, at first, that the stones were most probably
those of the wild species (*Prunus serotina* and *P. virginiana*), the
so-called black and choke-cherries, which are common enough in
this vicinity; though it was recognized at once as almost equally
probable that some of them were stones of the mazzard-cherry,
which is also well represented in this neighborhood. The question
was readily solved by comparing the fragments in the dung with
broken stones both of the wild and the mazzard-cherries which my
colleague, Mr. B. M. Watson, Jr., was kind enough to procure for
me. On making this comparison it appeared at once that the
stones both of the wild and of the cultivated cherry were repre-
sented in the dung, and that the larger part of the fragments in
the dung were those of the cultivated cherry, — manifestly because
of the greater hardness and thickness of these stones which hinders
them from being ground to powder so readily as the much thinner
stones of the wild-cherries. There was no lack, however, of frag-
ments of the stones of wild-cherries; and there is no room for
doubt that the pigeons had eaten indifferently the stones of choke-
cherries. of black-cherries, of mazzards, and of such of the culti-
vated varieties of cherries as may have been accessible to them.
Immediately after finding the dung, in October, I searched for
wild-cherries that might perhaps be still clinging to the trees and
was rewarded by finding some six or eight examples of the choke-
cherry adhering to fruit stalks which were still attached to the tree.
Still later, on November 5, in a pasture adjacent to the grounds of
the Bussey Institution, I found a couple of cherry-stones on the
ground beneath a wild black-cherry tree, thus proving that the
stones were still accessible to the birds. On breaking the choke-
cherry stones it appeared that the shells are almost as thin as those
of the black-cherry (*P. serotina*), from which indeed they can
hardly be distinguished by the naked eye.

When the dung was discovered the question arose whether the
pigeons might not have swallowed the stones accidentally, as it
were, when eating the ripe fruit. The wild passenger-pigeon is
known to be fond of many kinds of berries and probably eats the
fruit of the wild-cherry, as fruit. But this idea seemed hardly con-
sistent with the ordinary habits of the domestic pigeon, and it
speedily appeared that there was really no ground for assuming
that the birds had eaten any cherries, as cherries. It seemed most
probable, on the face of the matter, that the cherry-stones had been

eaten, as stones; either after the pulp had been removed by fruit-eating birds or when the pulp had decayed or dried up after the cherries had fallen from the trees to the ground. The correctness of this supposition was fully verified by the facts that wild-cherry stones were found on the ground as late as November 5, and that through all the autumn and winter months the pigeons continued to void upon the roof dung that contained a large proportion of broken cherry-stones, at times, that is to say, long after the fruit which formerly enclosed the stones had wholly disappeared.

At frequent intervals during six or seven months I carefully inspected the roof and continually collected fresh portions of the dung charged with fragments of cherry-stones from a place accessible to no one but myself, which was invariably swept clean after each collection had been made. The persistence of the appearance of the cherry-stone chips throughout the entire winter, even in times of snow and of severe frost, was so very remarkable that I am induced to print an abstract of my notes taken at the moments of observation. It will be seen that numerous fragments of cherry-stones were contained in the dung at all times and that it was only when the ground was pretty thoroughly covered with snow that any appreciable diminution in the number of the chips was noticeable. It is still a matter of surprise to me that the birds could have anywhere found so many cherry-stones during so long a period, particularly as they must have been subjected to the competition of squirrels and field-mice, which are by no means rare in the vicinity.

It should be premised that after the middle of October the birds were less frequently to be seen on the building than had been the case during the two previous months. As the weather became cool they changed their resting-place a few feet to a sunny nook where they were to be seen occasionally during the remainder of October and throughout November, December, and January. During February and March the visits were more rare, and they wholly ceased after April.

Collections made on the 5th, 10th, 15th, 20th, and 25th of November were abundantly charged with the broken cherry-stones, and the same remark is true of collections made at intervals in December. The weather remained open until January 1, 1882, on which day the roof was cleared of dung that contained many fragments of the cherry-stones. That night six or eight inches of snow fell which was badly drifted. The ground was, however, covered for the most part, and although there were some places which the wind had blown bare they were not frequent. Very cold weather

succeeded the snow until January 5, when the roof was again examined. Of the dung then collected comparatively few pieces were found to contain broken cherry-stones. On January 16 the roof was cleared again, the dung at that time containing an abundance of the cherry-stone chips. Next day there was a snow-fall heavy enough to cover almost everything, and a short spell of cold weather succeeded the snow. But the collections of dung made on the 19th, 21st, and 22d showed plenty of the cherry-stone chips, though the chips were somewhat less abundant than they had been before the snow. There were at this time considerable fluctuations of temperature, though the weather was on the whole cold. Enough snow melted each day at noon to leave some spots of land bare, though the ground froze very hard every night. It was noticeable during this time when the ground was nearly covered with snow that the separate pieces of dung were more voluminous, softer, and darker colored than they had been previously, as if the birds were now eating some berry or fruit; but I was unable to make out what this new kind of food was.

On January 22 a cold wind arose, and high winds persisted during the 23d and 24th with intense cold. Fahrenheit's thermometer ranging from 0° to 13° below zero. On the 25th of January the thermometer rose somewhat and the 26th was a warm day. Rain fell on the night of the 25th and froze firmly on the cold ground. But in spite of all this the dung collected on January 26 was all charged with broken cherry-stones. During the night of January 31, nine inches of snow fell; but it drifted badly, so that there were some bare spots left around houses and walls, much ground having been bare before the storm set in. Many broken cherry-stones were found in the dung that was swept off the roof on the morning of February 1. No dung was dropped on the roof during February 1, but on the 2d of February. and on the 3d also, collections of dung were made which contained an abundance of the broken stones. There was a small flurry of snow on the 2d which was badly drifted by a cold wind on the 3d. February 4 was a very cold day and the pigeons manifestly spent but little time on the roof. A few pieces of dung were nevertheless found there in the afternoon, and they contained plenty of broken cherry-stones. On the afternoon of February 4 snow began to fall and continued until noon of February 5. Some 13½ inches fell, which being added to that already on the ground made a very complete covering. The weather was very cold withal, but as the wind was high it is not impossible that some bare spots of ground may have been left. Not much dung was found on the roof on the morning of February 6, but some of it contained fragments of cherry-stones. No examination was made on the 7th. On the morning of February 8 there was only a small quantity of dung found on the roof, and it was of very different appearance from that ordinarily observed there, but it still contained some fragments of cherry-stones. No dung was dropped on the roof during February 9, 10, 11, 12, or 13, although a thaw had set in and many spots of land were bare by the 13th

and the ground was soft where bare. There was rain on the night of February 13, and warm weather continued during the 14th with bright sunshine. Much ground was bare on the morning of the 14th, and on the afternoon of that day two fresh watery droppings were found upon the roof, both of which contained many fragments of cherry-stones. The thaw continued during February 15, and on the afternoon of that day plenty of broken cherry-stones were found in the dung. The same remark is true of collections made on the 17th and the 22d. There was snow and sleet on February 21 so that the ground was pretty thoroughly and evenly covered. A small quantity of snow fell on the 22d also. The 23d was cold. No dung was found on the roof on the 23d, but twenty-four hours afterward a few pieces of dung were collected and they contained fragments of cherry-stones. On the morning of February 26 an abundance of dung was found, and there were plenty of cherry-stones in it. Not much of the recent snow had melted up to this time, though there were some bare spots of land as there doubtless had been all along. On the 3d of March, after several days of thaw and rain, large quantities of dung were found on the roof and very large amounts of broken cherry-stones were contained in it. My observations were interrupted by illness until April 6, when the roof was again swept clean. Much dung was found, all of it highly charged with broken cherry-stones. The month had been raw and cold and the season backward, so that grass was only beginning to show itself in warm sunny places. No dung was found on the roof on the 9th, 15th, or 17th of April. On the 22d a pigeon was seen to alight on the roof and remain there a short time, and on subsequent inspection one piece of fresh dung was found; it was full of broken cherry-stones. No other dung had been dropped on the roof since the clearance of April 6, nor was any ever found subsequently. The roof was examined on the 29th of April, the 25th of May, the 14th and 19th of June, the 2d, 6th, and 12th of July, the 25th of August and the 20th of September. The July and August observations are interesting since they were made at times after the new crops of cherries had ripened, so that their stones were doubtless abundant. It may be remarked that the weather was still cold and the season backward at the time when the last dung was collected on April 22. It was noticeable throughout the winter observations that the quantity of broken cherry-stones increased to a marked degree when the ground became bare, especially when the weather was warm enough to keep the surface of the ground from freezing. It was equally noticeable that both the amount of dung and the proportion of cherry-stones in it decreased whenever the ground was covered with snow and was frozen hard.

At intervals in April, 1882, I examined the gizzards of half a dozen or more pigeons that had been bought to be used as food. With two exceptions, where the birds had manifestly been purposely fed with Indian corn, I found nothing but a mass of oat-husks admixed with gravel.

In the beginning, before the completeness of the cherry-stone eating habit had been made out, questions presented themselves as to whether the hard cherry-stones might not possibly have been picked up merely in place of so much gravel for use in the gizzard, or have been mistaken perhaps for peas. The enormous quantity of shells collected certainly tends to invalidate the idea that the stones might have been used as gravel, though it is true enough that in case the stones were taken in for grinding purposes a continuous supply of them would have been needed to replace the incessant loss of those crushed and discharged. As regards the suggestion that the cherry-stones may have been mistaken for peas, it seems plain that *something* in their external appearance must have attracted the birds. It is not easy to believe that either the sense of taste or of smell can have led the pigeons to pick up the cherry-stones as food. If they did eat them as food for the sake of the kernels within the hard shell, by what conceivable means were they induced to do so? How were the birds informed of the small hidden store of food? and how wholly incommensurate with the nutritive effect of the kernels must have been the amount of force expended in crushing the enveloping shells. The whole question of the sense of taste in grain-eating birds is obscure enough anyway, and the present instance does but make the matter perhaps still more difficult of solution than it seemed before. To take, for example, a wholly dissimilar instance : Why is it that pigeons are so extravagantly fond of peas? As is well known, the domestic pigeon often causes serious trouble to farmers and gardeners by digging up recently sown peas — a kind of food which the bird appears to prefer to all others. I have myself repeatedly watched pigeons giving themselves an amount of trouble and hard labor in unearthing peas in a garden that could hardly be credited when seen. By repeated, powerful side-blows with the beak the earth is dug away and the seed finally laid bare. Professor Johnson * has remarked that " in the light and porous soil of the gardens of New Haven peas may be sown six to eight inches deep without detriment, and are thereby better secured from the ravages of the domestic pigeon." It might be argued that inasmuch as the pea contains a large proportion of albuminous constituents it may satisfy a natural craving of the pigeons for nitrogenous food. But if this be really the attraction, why are not the birds fond of the

* In his " How Crops Grow," New York, 1868; p. 316.

equally nitrogenous bean? why should they not eat the little " pea-bean," for example, as readily as the pea itself? and if they are anxious to get nitrogen why do they not eat animal food at all times as they are known to do occasionally? It was noticed long ago by Snell * in Germany that the domestic pigeon sometimes eats garden-snails, both the species provided with shells and those which are naked, as well as earth-worms, several kinds of smooth caterpillars, notably *noctua segetum*, and maggots and meal-worms when they are to be got. Throughout the summer months he found minute eggs also in the crops of his pigeons which were apparently the eggs of snails. Here in Cambridge, Jeffries Wyman,† on the occasion of his dissecting a young domestic pigeon " taken from the nest and still covered with down," found the crop very largely distended with canker-worms (larvæ of *Anisopteryx pometaria*) in all stages of digestion. Wyman estimated that as many as 660 of the canker-worms must have been contained in the crop of this one squab, and that the mass was nearly equal to one third the weight of the bird.

The importance of animal-food for young birds has often been insisted upon ‡ but it is noteworthy how easily most persons have hitherto overlooked the fact that the rule is applicable even to the domestic pigeon as well as to other birds.

With regard to the cherry-stones it seems not improbable that a certain comfort and satisfaction may be derived by the birds from the long-continued distention of their organs of digestion by this very bulky material, and this may perhaps have been the incentive which led the birds to accustom themselves to a diet apparently so meagre. It was very noticeable, at all events, that the pigeons observed by me took particular pains to resort to a quiet nook where they were free from interruption while digesting this food ; so much so, indeed, that I frequently asked myself how these particular birds could possibly find time for the ordinary affairs of life. During August and September, that is to say at the time when cherry-stones were to be had in abundance, the two birds often remained for hours in a state of quiescence so unusual that it was repeatedly

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* " Jahrbücher des Vereins für Naturkunde in Nassau," 1857, Heft 12, p. 361.

† " Proceedings Boston Society of Natural History," 1866, **11.** 24.

‡ By no one, perhaps, more explicitly than Wm. Bartram in the introduction (p. XXIII.) to his " Travels through North and South Carolina, Georgia, Florida, &c," London, 1792, when he asserts that " animal-substance seems to be the first food of all birds, even the graniverous tribes."

remarked upon both by myself and by members of my household at a time when we had no inkling that the birds had been consuming a particularly indigestible food. It is not impossible, on the other hand, that the satisfaction derived from the cherry-stones may be due to the chemical composition of their kernels rather than to any mechanical action. It is true at all events that the meat within cherry-stones, both that of the wild and of the cultivated species, has a very strong flavor of bitter-almonds, which indicates the presence of prussic acid, and it is within the bounds of possibility that this component of the kernel may act as a sedative or composing medicament and so comfort the birds. However this may be, it is none the less extraordinary that birds accustomed to flying and whose safety must often depend upon the power of instant and speedy flight should willingly load themselves down with such quantities of heavy ballast. It is known from European experience that the domestic pigeon, besides eating many very hard seeds of weeds, is extremely fond of beech-nuts. So, too, the wild passenger-pigeons of America, and the Carolina turtle-dove also, eat beech-nuts and acorns. But while less unlike cherry-stones than most other items in the ordinary diet of the domestic bird, the shells of these nuts seem like mere paper when compared with the hard lignine of the cherry-stones.

As bearing on the question of the value of pigeon-dung as a fertilizer it is worthy of remark that the observation above described goes to show the possibility that at certain seasons of the year the sweepings of the dove-cote may be largely composed of matters that are inert and of themselves useless as manure ; in which event it would be erroneous to repose too securely upon the traditional high estimation in which this form of manure has always been held.

NOTE 1. — Since the foregoing article was written I have observed that Snell,* in discoursing upon the influence of experience on the selection of food by animals, has alluded in a somewhat different sense from that above stated to the notion that pigeons may mistake cherry-stones for peas. " Young doves," he says, " pick up cherry-stones and throw them away again after they have convinced themselves, by (repeatedly) taking them in their beaks and again dropping them, that they are not peas." Snell's observation is of interest, however, as going to show that the birds only gradually accustom themselves to this seemingly unnatural food.

* " Jahrbücher des Vereins der Naturkunde in Nassau," 1861, Heft 16, p. 208.

NOTE 2. — In July, 1883, I learned that a dozen or more of pigeons had for a long time made their home in an unoccupied hay barn on the Bussey Farm, half a mile from the school-building above referred to. This barn had been shut up, out of use, for several years and there was half a barrel or more of the dry dung of the birds in one heap upon the floor.

It was evident, at the first glance, that this dung differed very much as to its composition and general appearance from the dung that had been collected on the school-building in previous years. A large majority of the separate pieces of the dung from the barn consisted well-nigh completely of the husks of oats, manifestly obtained from horse-dung that had been dropped in the adjacent roads ; but there were, nevertheless, numerous bits of the dung that contained fragments of cherry-stones, and some pieces of the dung contained many of these fragments. After a little practice it was easy to distinguish almost immediately the cherry-stone dung from that composed of oat-husks, so widely did the two kinds differ in color and general appearance. It was noticed that the pieces of dung charged with broken cherry-stones seemed to be equally abundant in all parts of the heap, i. e. there were as many of them in the dung that appeared to be old as in that which had only recently been dropped. There were, moreover, a large number of cherry-stone chips in the loose " dirt " between the separate pieces of dung. A few pieces of dung were encountered that consisted almost wholly of cherry-stone chips, though as a rule there were comparatively few bits of this dung so highly charged with the fragments as the dung on the school-roof had been habitually. It was noticeable in this collection from the hay barn that either one or the other of the materials — oat-husks or cherry-stone chips — was usually largely predominant over the other in any given piece of the dung, though sometimes the two constituents were pretty evenly admixed ; and even in those bits where the oat-husks were most abundant some fragments of cherry-stones could often be detected among the fibres. It was evident from all this that the consumption of cherry-stones had not been peculiar to the single pair of birds I had previously studied, and that the practice was in no wise confined to them. It is manifestly a common habit of suburban pigeons in this region to eat cherry-stones, and the fact is probably true of pigeons in all localities where this form of food is accessible. On August 23, 1883, as I was strolling in the early morning on the town hill just behind the village of Provincetown,

Mass. — of all places in the world — I came suddenly upon a solitary domestic pigeon feeding on the sandy ground at the edge of a clump of low bushes. On examining the place whence the bird flew, I found that the "bushes" were stunted wild-cherry trees and that they were loaded with fruit. As there was not even a suggestion of any other kind of food in the neighborhood, there was no reason to doubt that the bird was really eating cherry-stones (or perhaps cherries) which had fallen from the trees or been dropped by other birds.

The abundance of oat-husks in the dung found at the hay barn gives emphasis to the fact that oat-husks were seldom or never detected in the dung at the school, although the school birds had equal or perhaps better opportunity than the others to procure oats from horse-dung; and the great mass of this worthless material again suggests a doubt as to the general validity of the popular opinion as to the high value of pigeon-dung as a fertilizer. There is always as a matter of course some uric acid in pigeon-dung, even in that which is most highly charged with inert matters; and since uric acid is known to be an extremely powerful manure, the dung must be valuable, chemically speaking, somewhat in proportion to the amount of this ingredient, — which is doubtless large in some cases, as when for example the diet of the birds is peas, or indeed almost any kind of huskless grain. But it is not unlikely that the special merit of the dung may depend not so much upon its chemical composition as upon the presence in it of some active "ferment," or upon some special fitness which the dung may have for harboring the ferement. The idea is suggested by the traditional use of pigeon-dung as a ferment by the morocco-dressers; and it is borne out in some part by the fact that pigeon-dung was formerly highly esteemed in the preparation of nitre-beds also. Indeed, Pietsch * is said to have written, in 1749, that for salpetre-making pigeon-dung does better than any other kind of excrement.

The cherry-stones eaten by the barn-pigeons were manifestly of the wild species for the most part, as was not unnatural in view of the greater distance of the locality from gardens and fruit-farms as compared with the school-building. In harmony with the comparative thinness and tenderness of the shells of the wild-cherry stones the fragments found at the barn were in general smaller

* Cited by the authors of the "Recueil des Mémoires sur la Formation du Salpêtre," in "Mémoires des Savans Étrangers," 1786, **11.** 24.

than those collected at the school. But the question still suggested itself whether, since the school birds had evidently eaten many more cherry-stones than the birds at the barn, it may not have happened that they became more accustomed to the digestion of the stones. It is not impossible, perhaps, that they may have even acquired a habit of discharging the useless fragments speedily. The very fact that the gizzards of the birds were habitually distended with the stones may possibly have led to the more rapid evacuation of the fragments. It seems improbable, withal, that birds whose gizzards were incessantly full of cherry-stones could have felt very keenly the usual need of swallowing bits of gravel; so that the fragments of the cherry-stones may not have been long subjected to the ordinary grinding-process. That is to say, it may well have been true that there was actually used by the birds at the barn an implement (gravel) better fitted for crushing the cherry-stones than was employed by the birds at the school. Even in the barn-dung, however, one or two fragments as large as half a cherry-stone were found, manifestly of the cultivated cherry; and as many as seven whole stones of one or the other wild species were collected which had passed unbroken through the birds. On cracking these stones a perfect kernel was found within the shell in every instance. Several quartz pebbles were found also, as before; and three or four very hard minute, glistening black seeds of some herbaceous plant which had passed through the birds unharmed; but in general the comminution of the indigestible matter was remarkably thorough.

It is worthy of remark that some botanists and geologists appear to have occasionally lost sight for a moment of the completeness of the trituration to which the food of grain-eating birds is subjected. The fact certainly militates strongly against the idea which has sometimes been suggested, that seeds and the stones of fruit are transported and scattered by such birds. It is true of course that many fruit-eating birds are active agents in disseminating seeds and fruit-stones, for they may either eat only the pulp of the fruit and leave the stone intact at the place to which they have carried it, or they may disgorge the seeds of berries after the fleshy portion has been digested, or the seeds may pass off undigested in the dung. But it seems plain that with birds whose gizzards are habitually occupied in grinding grain it is only in rare instances that any seeds can escape digestion. The occasional bits of gravel, as well as the unbroken cherry-stones and the black seeds found in

the pigeon-dung as above described, had manifestly escaped by some very unusual accident; the fact of their appearance does but enforce the truth that effective pulverization is the general rule. It is conceivable, perhaps, that if the birds were made to eat unusual quantities of pulpy fruits an appreciable portion of the seeds or stones might pass through them undigested. Indeed, this hyphothesis seems to be the only one capable of explaining the following citation from Sir James E. Smith: * " Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines and are deposited far from their original place of growth in a condition peculiarly fit for vegetation. So well are the farmers in some part of England aware of this fact that when they desire to raise a quickset hedge in the shortest possible time, they feed turkeys with the haws of the common white-thorn (*Cratægus oxyacantha*) and then sow the stones which are ejected, whereby they gain an entire year in the growth of the plant."

The practice cited by Smith as formerly habitual with English farmers deserves to be investigated; for inasmuch as the turkey often feeds on acorns, pecan-nuts, and even English walnuts, it is evident that there is no lack of crushing power in his gizzard. In this respect the gizzard of the turkey would naturally be supposed to stand next in order to that of the proverbial ostrich, of which Tristram,† writing at Tuggart in the Sahara, remarks that he saw " tame ostriches dodging among the strolling French soldiery to pick up the date-stones they dropped as they sauntered by."

Possibly the foregoing statement of Smith may have had its influence on the following sentence of Darwin : ‡ " I have never seen an instance of nutritious (soft?) seeds passing through the intestine of a bird, but hard seeds of fruit pass uninjured through even the digestive organs of a turkey. In the course of two months I picked up in my garden twelve kinds of seeds out of the excrement of small birds, and these seemed perfect and some of them which I tried germinated."

Several species of pigeons at New Guinea, the Moluccas, and New Hebrides have been described as swallowing the fruit of the

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* " Smith's Introduction to Physiological and Systematic Botany," p. 304. Copied in " Lyell's Principles of Geology," p. 602 of 8th edition.

† In his " The Great Sahara," London, 1860, p. 276.

‡ " On the Origin of Species by means of Natural Selection," London, 1860, chap. XI. p. 361.

wild nutmeg, though doubts have arisen as to whether it is not the outer or fleshy substance alone that affords them nourishment, and some travellers have asserted that the nut itself is voided whole. I am unable to refer to recent observations on this point. Possibly the particular pigeons now in question may belong to fruit-eating and not to grain-eating species. The fact that the nutmegs are swallowed whole is undoubted, however, and it is of special interest as bearing on the question of " ballast," to which allusion has previously been made. An English writer has expressed his surprise, in commenting on these large nutmeg-eating pigeons, with the remark that " tame pigeons in England are often choked with small horse-beans." But Audubon has said of the passenger-pigeon of this country, " Whilst feeding, their avidity is at times so great that in attempting to swallow a large acorn or nut they are seen gasping for a long while, as if in the agonies of suffocation." So also Mr. Jefferies,* writing of the environs of London, says, " Rooks come to the oaks in crowds for the acorns ; wood-pigeons are even more fond of them, and from their crops quite a handful may sometimes be taken when shot in the trees. . . . Never was there such a bird to eat as the wood-pigeon."

* R. Jefferies, " Nature Near London," London, 1883, p. 177.

No. 30. — *Notes on Certain Physical Characters of two Common Grasses*. By the late Lester Sackett Ford, B.A.S., M.D., Demonstrator in Anatomy at the Bussey Institution.*

I. *The awn of Holcus lanatus (velvet-grass or meadow soft-grass)*. It is customary in botanical text-books to depict the awn of the so-called velvet-grass, meadow soft-grass, or wooly soft-grass (*Holcus lanatus*) as bent or curved or hooked at the outer extremity. But when examined as it stands in the fields, at least while the plant has not yet passed its prime, the awn will be found to be straight and in no wise bent or curved. It is in the process of drying that the tip of the awn often curls over. The descriptions in many of the books are not only erroneous as to the fact, but by giving undue prominence to the curled awn they are liable to mislead those beginners in botany who are so situated that they can study the fresh and unwilted grass, or who happen to meet with specimens which have dried or wilted under such conditions that most of the awns have remained straight. In general, rapid drying seems to favor the curling of the awns. By bringing the recently plucked grass into a warm room, placing it in hot sunshine and watching with a magnifying-glass, it is easy to arrange matters so that the awns can actually be seen to curl. As soon as the process has once begun it goes on rather rapidly, and it may readily be exhibited to a class. It was while studying under these conditions a specimen of grass that could not be made to correspond with the descriptions in the books that the straight awns of the specimen were seen to suddenly resolve themselves into the conventional hooked awns of *H. lanatus*.

The awns do not by any means invariably curl in drying, and consequently it would not be strictly correct to say that in dried specimens the awns are bent; the description should read, rather,

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* It happened that these botanical observations of my lamented friend Ford were made so immediately under my own eye that I have no hesitancy in reporting them and vouching for their correctness. My only scruple is lest, through my own ignorance of matters botanical, I may omit some detail which might seem important to an adept. I can but wish withal that it were in my power to convey an adequate idea of the acumen, the accuracy, and the high scientific spirit which the man brought to bear upon these simple studies as upon everything which he touched. — F. H. Storer.

that the awns are normally straight but many of them curl in the process of drying. It is noticeable also that, in drying, the points of some of the awns curl one way and some another; that is to say, some of the awns bend inward toward the centre of the flower and others bend outward. The same diversity in direction will be found in the figures given in the books. Thus, Professor Asa Gray, in his "Manual of the Botany of the Northern United States," gives a figure of the awn of *H. lanatus* that has a pronounced curl outward; and several other authors might be mentioned who give somewhat similar figures, among them J. S. Gould, in his essay on "Grasses and their Culture," published in the "Transactions of the New York State Agricultural Society for 1869," p. 351, plate 53, fig. 184. So too Langethal, in his "Die Süssgräser," Jena, 1855, p. 84, table IV., makes the awn curl outward though in a much feebler way than Gray. But Jessen, in his "Deutschlands Gräser," Leipzig, 1863, pp. 56, 106, figures the awn of *H. lanatus* with an emphatic hook inward. There are some figures in Ettinghausen & Pokorny's "Physiotypia Plantarum Austriacarum," Vienna, 1855, vol. I. plate 97, which are specially interesting in their bearings on this note because they were made by the nature-printing process (phytoglyphy) and must necessarily truly represent the dried plants from whose imprint they were taken. In these figures most of the awns turn inward toward the centre of the flower, while some turn outward and some are straight. Many straight awns are visible also on a typical dried specimen of *H. lanatus* contained in a collection of the agricultural grasses of Germany, made by Dr. A. B. Frank, Custodian of the University Herbarium at Leipzig, which belongs to the Bussey Institution. It is true, moreover, that several of the books relating to grasses that are contained in the library of the Bussey Institution * give figures in which the awns of *H. lanatus* are represented as being straight. Indeed, several authors recognize two species or varieties of *holcus* — the one called *H. lanatus* and the other *H. mollis* — which really appear not to differ from one another in fact any more than fresh and dried specimens of the plant *H. lanatus* do naturally differ. Langethal tells of the prominent awns of *H. mollis* and the short awns of *H. lanatus*, and he figures them also; but a comparison of his figures suggests the thought that the *lanatus* awns

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* It should be said that in reporting these notes I have confined myself to the references and authorities which were readily accessible to Mr. Ford, and which I know were consulted by him. — F. H. STORER.

appeared to be short merely because their extremities had curled
downward. Wittmack, in his "Gras- und Kleesamen," Berlin,
1873, figures the awn of *H. mollis* as being nearly straight, while
the awn of *H. lanatus* he represents as bent outward away from
the interior of the flower. Long awns are indicated for both the
plants. In the text also he describes the awn of *H. lanatus* as
hooked and that of *H. mollis* as not hooked. Schmidlin, in his
"Abbildung und Beschreibung der wichtigsten Futtergräser,"
has a figure of *H. mollis* as covered with long straight awns, a few
of which are slightly twisted ; while in his figure of *H. lanatus* only
a few awns are shown anyway, and those are comparatively short,
though with a single exception they are all straight. Jessen, in
his "Deutschlands Gräser," gives on pp. 52 and 105 a figure of
H. mollis showing a long straight awn ; and on pp. 56 and 106 he
gives a figure of *H. lanatus* with a hooked awn, the hook looking
inward toward the interior of the flower as was said above ; but on
p. 221, where the two species or varieties of the grass are con-
trasted, the same figures are given again, now side by side with
the names transposed. Here the hooked awn is credited to *H. mol-
lis* and the straight awn to *H. lanatus*. That this transposition of
the figures was unintentional appears from the descriptions in the
text. On p. 106 it is distinctly stated that "in *H. lanatus* a hooked
awn often projects beyond the palet," and on p. 222 it is said that
"*H. lanatus* has awns which are hardly so long as the palets, while
the awns of *H. mollis* are appreciably longer. In *H. lanatus* the
awn is first straight and then bent, while in *H. mollis* it is knee-
shaped but never curved." In Wm. Hamm's "Grundzüge der
Landwirthschaft," **2.** 324, the more strongly magnified figures of
the flowers proper show a straight awn on *H. mollis* and no awn on
H. lanatus, while the less highly magnified figures of the tufts of
flowers seem to show straight awns in both cases. C. L. Flint, in
his "Practical Treatise on Grasses and Forage Plants," New York,
1857, pp. 68–70, gives the same figures as Hamm, with the excep-
tion that for *H. lanatus* the magnified flower shows an awn that is
inclined obliquely. Flint's description of the awn of *H. lanatus*
follows that of Professor Gray, and so does Killebrew's, in his
"Grasses of Tennessee." To cite one other authority, it was
noticed after the foregoing observations had been made that a
highly pertinent word concerning them had been written long be-
fore they were made in a copy of "Gray's Manual," which is kept
in the Bussey Library. At the paragraph where Professor Gray

states that the upper flower of *H. lunatus* bears a stout bent awn below the apex, there is a brief marginal note in the hand-writing of the well-known botanical collector, Mr. Charles Wright, who simply underscored the word "bent" in the text and wrote the word *straight* on the margin of the page. Evidently he too, in previous years, — at the time when he was connected with the Bussey Institution, — had examined fresh specimens of the grass from the adjacent meadow, and had not failed to recognize the discrepancy between the appearance of the fresh flower and the printed description of it.

II. *Vitality of the cleistogamous seeds of Danthonia spicata (white-top or wild oat-grass).* In an interesting and important paper published in 1878, Mr. C. G. Pringle * has shown that, in addition to the ordinary tufts of seeds at the summit of the stem, the "white-top" or "wild oat-grass" which infests so many poor pastures in Northern New England bears numerous spikelets of seeds just above each joint of the culm and hidden within or beneath the sheaths of the leaves. Mr. Pringle dwells on the importance of these cleistogamous seeds as a means of disseminating the worse than useless grass and upon the consequent difficulty of coping with it in old mowing-fields and pastures. He argues with much force that the unparalleled and irresistible spread of the plant in recent years attests the efficacy of the means provided for its dissemination. Relying doubtless on the known fertility of cleistogamous flowers, he does not say explicitly that he has ever tested the germinative power of any of the seeds that have grown beneath the leaf-sheaths. In order to determine this question a number of the hidden seeds were picked out from beneath the leaf-sheaths of dried specimens of the grass which had been collected in the previous year and preserved in an herbarium, and the seeds were planted in loam that had been calcined in a muffle for the purpose of destroying all traces of organic matter. The roasting to which the loam was subjected would of course destroy any seeds — whether of grasses, weeds, or other plants — which might have been contained in the earth originally. The pots that held the loam and the seeds were placed in a greenhouse and were watered with distilled water at first, and afterwards with a highly dilute solution of saltpetre (1 : 1000). Under these conditions, and in

* "Fifth Report of the Vermont Board of Agriculture, for the Year 1878," p. 242.

spite of the fact that many of them had a very unpromising appearance, a large proportion of the seeds germinated and grew freely, thus fully corroborating Mr. Pringle's views and illustrating yet again the pestiferous character of the danthonia.

I have an impression that Mr. Ford tried precisely similar and simultaneous experiments with the ordinary seeds of danthonia taken from the tops of his dried specimens of the grass, and that he found that they too germinated freely ; but I am not perfectly sure as to this point, and I mention it merely as a supposition. It is only with regard to the cleistogamous seeds that I feel perfectly sure of the results as above stated.

From Mr. Pringle's figures and description it appears that the habit of cleistogamous flowering is possessed not only by *D. spicata*, but by the allied species *Danthonia compressa*, — which grass, as my colleague Mr. C. E. Faxon assures me, is a perfectly distinct species and not uncommon in the vicinity of the Bussey Institution. Professor Gray, in a note to the chapter on cleistogamy in his "Structural Botany," New York, 1880, part I. p. 241, speaks of other cleistogamous grasses in the following terms : "Amphicarpum (*Milium amphicarpon*, Pursh) is the earliest recognized cleistogamous grass, except perhaps *Leersia oryzoides*. Some species of Sporobolus are like the latter. and Mr. C. E. Pringle has recently detected such flowers concealed at the base of the sheathes of Danthonia [also in Vilfa and other grasses. Amer. Jour. Sci., 1878 [3.], **15.** 71]." As bearing upon this matter, it would be of interest to notice whether a "strange and peculiar property of fowl-meadow grass," mentioned as long ago as 1747 by the Reverend Jared Eliot in his "Essays on Field Husbandry," [*] may not perhaps depend upon the existence of cleistogamous spikelets in this grass also. According to Eliot, the fowl-meadow grass "will hold out to be in season for cutting from the beginning of July till some time in October." "This fact I (he) wondered at, but viewing some of the grass attentively I think I have found the reason of it. When it is grown about three feet high it then falls down, but doth not rot like other grass when lodged ; in a little time after it has thus fallen down at every joint it puts forth a new branch. Now to maintain this young brood of suckers there must be a plentiful course of sap conveyed up through the main stem or straw ;

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* The citation is from the reprinted essay in "Papers for 1811, Communicated to the Massachusetts Society for Promoting Agriculture," pp. 55, 73.

by this means the grass is kept green and fit for mowing all this long period. Whether this young growth from the joints be owing to the horizontal position of the straw, or whether it is a confirmation of that doctrine that the joints of plants are seed-vessels, I leave to naturalists to determine."

From the description as here cited it seems not unnatural to suppose that spikelets may be hidden from the beginning at the joints of the grass, and that they may shoot up as stated when the grass has lodged ; though it would seem to be still more probable that the growth noticed by Eliot was nothing more than a particular instance of the well-known method of propagation known to gardeners as layering, — *i. e.* new shoots, and new roots also, may have struck out from each of the joints of the recumbent grass, although no spikelets had begun to grow there before the grass was thrown down.

No. 31. — *Some items of American experience which suggest that Potassic Fertilizers may perhaps act in several different ways.* By F. H. STORER, Professor of Agricultural Chemistry.

IN an interesting and important essay published a few years since Professor Adolf Mayer,[*] of Wageningen, has set forth in considerable detail the results of a critical study of numerous European experiments with potassic fertilizers, and has formulated several " practical conclusions " relating to the use of potash-compounds in agriculture.   Among the numerous points suggested by Mayer there are several which are specially interesting to Americans, more particularly those relating to facts which were already familiar to many persons in this country from the study of their own experiments and observations and the teachings of agricultural experience such as a new country affords ; and it is worthy of record that in several particulars the observations of Mayer and of his American predecessors do mutually support and strengthen one another.   It is true withal that some of the results recorded by earlier European observers and experimenters which have not been noticed by Mayer consist very well with conceptions that are now commonly held in this country.   There is indeed, in some respects, a curious parallelism between the farming experience which was gained in some European countries a century or two ago and that which finds place in certain American districts to-day, or which did at all events exist in them very recently.   And it is probably true in general, as it would seem to be in this special instance, that the agricultural critic who has it in his power so to do will find an advantage in considering his subject in the light of the earlier evidence as well as in that of testimony which has been more recently adduced.   Thus with regard to certain particulars dwelt upon by Mayer, there are facts of American experience, and of old European experience as well, which point with considerable force to the significance of " mitigating circumstances," and which seem to call for some qualification of one or two of the more extreme statements which have been made by this chemist.   The reader is impressed withal with a conception of the very different

* " Die landwirthschaftlichen Versuchs-Stationen," 1881, **26.** pp. 77, 309.

attitude of mind in which potassic fertilizers are regarded now-a-days, by farmers and investigators, in the high-farming districts of Holland and North Germany and in our own land of "extensive" pastures and meagre mowing-fields.

In the present paper I wish to enumerate some of the results which have been obtained in this country, more especially those that relate to matters which Professor Mayer has not noticed. I do not propose, however, to enter upon any formal criticism of Mayer's work, or even to touch upon it, excepting in so far as it may serve occasionally to support or illustrate my story.

A. — *Carbonate of potash (wood-ashes) does good on many light lands by agglutinating the particles of the soil in such manner that the condition of the land is improved as regards its capacity of retaing moisture. Conversely the potassic carbonate may do harm on clays — and on some loams whose particles are very finely divided (silt lands) — by increasing their plasticity, which is naturally only too pronounced.*

In so far as this particular effect of tempering earth is concerned, carbonate of soda produces similar results to carbonate of potash; and the subject may readily be illustrated by a reference to the so-called alkali-lands of the West, whose peculiarities have been described by Professor E. W. Hilgard,[*] of the University of California, both in "Silliman's Journal" and in the "Pacific Rural Press," of San Francisco. To quote from Hilgard: "Soils impregnated with alkaline carbonates may generally be recognized by their extreme compactness and their refractoriness under tillage, and by the fact that they usually form "low spots" in the general surface of non-alkaline land, where turbid clay-water dark with dissolved humus will lie for weeks after the higher land appears dry." Agriculturally speaking, the trouble with such land is that it cannot be properly tilled by the ordinary mechanical appliances.[†] No matter how often it may be ploughed or harrowed such a soil will remain a mere mass of hard, broken clods; the particles of earth cannot be brought to the fine, crumbly, mellow condition

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[*] "American Journal of Science," 1879 (3), **17.** 211. "Pacific Rural Press," 1877–1880.

[†] As is well known to agricultural students, Professor Hilgard has overcome the difficulty, in cases where the amount of alkali is not too excessive, by chemical means; viz. by strewing gypsum enough on the land to decompose the alkaline carbonate. Drainage is of course to be resorted to also when possible.

which constitutes good tilth. In presence of the alkaline carbonate, the particles of earth cohere in such wise that the furrows made by the ploughshare will neither fall down to powder on drying nor break up to powder when a harrow is dragged across them. In the words of Professor Hilgard: "The result (of ploughing and harrowing) was a seed-bed of soil-clods ranging from the size of a pea to that of a billiard-ball, but no tilth."

But it is plain that on land naturally so loose and porous that it stands in need of being compacted, the presence of a small proportion of the alkaline carbonate — *i. e.* a just and proper proportion — would do good by enabling the soil to hold more water in its pores, and to hold it longer and more firmly than could have been done if none of the alkali were present. The idea is simply that many an open, leachy soil will be improved if its particles can by any means be held together a little more tightly than they are held naturally, so that water may be retained more forcibly or perhaps lifted more readily. It was presumably on this account that the farmers of Norfolk County in England laid so much stress on having their light soils trampled down firmly by means of cattle or sheep that were fed upon the land, and that the Scotch long since resorted to the use of heavy rollers upon light land. Looking at the matter in this way, it may perhaps be said with truth of some of the alkali-soils that the trouble is that they contain too much of a good thing.

But even if the alkali-lands of California had never been studied it would still be known tolerably well from practical experience with wood-ashes that carbonate of potash can " bind " light soils. It is a familiar fact of farming experience here in New England that wood-ashes are most highly esteemed — because they do their best service — precisely on light, leachy loams, such as often overlie the coarse gravel of the drift.

It has long been known moreover that wood-ashes do help the soil to retain moisture, and this point has been insisted upon in the following terms by Mr. Lorain,* one of our earlier agricultural writers. When land is cleared, "the fallen timber is cut up into proper lengths, hauled or rolled together, heaped up and burned. The brambles and sprouts, toge her with the bark, brush, chips, etc., are gathered by hand and raked into small heaps and also burned. It often happens, however, that the ashes arising from

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* John Lorain, "Nature and Reason Harmonized in the Practice of Husbandry," Philadelphia, 1825, p. 87.

burning the heaps are not spread, except the little that is done towards spreading them by the plough and the harrow in the cultivation of the soil. . . . Thus accident furnishes the means of much more correct information of the effects of fire on soils than any chemical experiments that have been or perhaps ever will be made. This being the case, the backwood's farmer at one comprehensive view may readily see the effects produced by every different grade of burning and on every different kind of soil. He may likewise readily discover the effects produced by the different grades of burning, by comparing what takes place where the log-heaps, brush-heaps, etc. were burned, with what happens in the grounds around them which have not been subjected to the burning. The salts contained in the ashes where the heaps were burned, especially where the log-heaps were consumed, keep the soil so moist for some time after the grounds have been cultivated that until I have got near enough to investigate the cause of this moisture I have sometimes thought that it proceeded from spouts or feeble springs. This moisture causes the crops to be as luxuriant on sandy soils as on clay. It counteracts the injurious effects produced by too great evaporation, which gene ally takes place in sandy grounds after they have been robbed by burning or an injudicious cultivation of the greater part of the animal and vegetable matter that had previously existed in them."

I have myself seen, upon the Plain-field of the Bussey Institution, this compacting effect of carbonate of potash produced in very marked degree. A plot that had been dressed exceptionally heavily with wood-ashes during four consecutive years was finally ploughed, in dry summer weather, together with the rest of the field. It then appeared that the soil of this particular plot was so firmly bound that a yoke of oxen had considerable trouble in dragging a plough through it, and that the furrow where it crossed this plot was a mere mass of large hard lumps or clods, though the soil of the remainder of the field was mellow enough and was ploughed without any difficulty. Yet through all the years of the experiment the plot now in question had borne luxuriant crops and had manifestly been better supplied with moisture than any of the other plots in the vicinity. I could not see any reason for believing that the well-known power of carbonate of potash to attract water from the air had anything to do with the appearances here described. On the contrary, it is highly improbable that the easily soluble carbonate could have remained long, as such, in the soil of

this particular field. Carbonate of potash would naturally soon be washed out of the soil almost anywhere, or decomposed by reacting chemically on matters in the earth. In all probability the compacting effect is produced immediately on the addition of the carbonate, or soon afterward, and it is manifestly something which endures long after the carbonate of potash has ceased to exist in the soil as such. There is an old remark of Sir Humphrey Davy * which is not inconsistent with the facts and views here presented. He says : " The general tendency of the alkalies is to give solubility to vegetable matters. . . . The vegetable alkali (potash) likewise has a strong attraction for water, and even in small quantities may tend to give a due degree of moisture to the soils or to manures ; though this operation, from the small quantities used or existing in the soil, can be only of a secondary kind." It is not impossible that Davy may have been told by some of his agricultural acquaintances of the fact that wood-ashes tend to keep land moist.

The significance of the agglutinative power of the alkaline carbonates, and the danger of employing them in improper situations, may be still further illustrated by considering their action upon clay. It is a known fact that alkaline lyes added to clays tend to " puddle " them,† — i. e. to make them even more sticky, adhesive, and impermeable than kneading with mere water would ; while lime, as well as salts of lime and various other saline compounds, act in a contrary sense to diminish the adhesiveness. It is said that clay which has been kneaded with saleratus-water will " set " with peculiar firmness on drying. This peculiarity is sometimes put to practical use in domestic economy, as when mixtures of sifted wood-ashes and clay stirred up with a little water are used as a cement for stopping cracks in stoves and holes in stove-pipes. The common remark of our farmers that wood-ashes are excellent on gravelly or sandy soils would naturally suggest the inference that experience has taught them not to employ such ashes on stiff clays.

B. — *Carbonate of potash (wood-ashes) favors the decay of humus (or other organic matter) in the soil in such wise that the nitrogen of the humus is made fit for the support of plants.*

I have already discussed this property of the potassic carbonate

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* " Elements of Agricultural Chemistry," p. 229 of the Philadelphia edition of 1821. .

† Hilgard, " Pacific Rural Press," 1878, **15.** 130.

so fully in an earlier number of the Bussey Bulletin * that it would be mere repetition to dwell upon the subject here. It will be sufficient for my present purpose to say that wood-ashes have long been used in this country for composting peat, and that it is reasonable to suppose that if the potash carbonate can act so powerfully in the compost-heap to change the nitrogen of humus, it will have a somewhat similar action upon the humus in a soil when it is merely spread upon the land. This effect was noticed by Lorain in connection with his observations on the cementing action of wood-ashes mentioned above on p. 346. He says: "I was not a little surprised when I first removed to the backwoods to find that vegetation, in place of being destroyed by the very large quantity of ashes lying within the compass of the spot where a log-heap had been burned, was commonly much more luxuriant than on any other part of the ground, unless the soil was in general rich enough to produce luxuriantly." And again he says: "If the crop happens to be wheat or other small grain it often falls or lodges where the heaps of logs were burned, but is less likely to be injured by superabundant luxuriance where brush or brambles were consumed."

In some of my own field-experiments this property of carbonate of potash was particularly noticeable. Thus on the plot that was heavily dressed with wood-ashes — mentioned on the previous page as an instance where a soil was firmly compacted by the alkali — the plants grew almost as rank and succulent as if they had been manured with dung.† So too when ashes are spread as a top-dressing on grass-land, the improved color of the grass shows clearly that it has access to nitrogenous food. I have been assured by Mr. J. H. Adams, a gentleman familiar with the cultivation of tobacco, that there is a practical objection to the use of wood-ashes as a manure for this crop, at least as regards the better kinds of tobacco, in that it makes the plants grow coarse — doubtless because of nitrogen from humus which the alkali brings out. It is interesting to note that the same word is used by other tobacco-growers in cases where the influences which promote the rank growth are unmistakably nitrogenous. Thus it has been written: "Blood-fertilizers and cotton-seed meal tend to make tobacco coarser. . . . On new land tobacco has larger stems and

* Vol. I. pp. 270, 387 et seq.

† Compare Bussey Bulletin, I. pp. 127, 270, 314, and the tables which include plot "BB. 4."

fibres ; the texture is coarser." Good crops were obtained in my own field-experiments from heavy dressings of carbonate of potash (pearl-ash) used upon rutabagas, beans, and barley, and it has occasionally been used * in field-practice in this country — notably as an application for potatoes. The results were favorable when the dressing of potashes was not too heavy. Mayer tells of a number of good results that have been obtained abroad by the use of carbonate of potash with beets, potatoes, and tobacco, though reports adverse to its use are not wanting ; so that from a comparison of many European trials he concludes that it is a highly capricious manure. It will be noticed that this conclusion plainly supports the argument that carbonate of potash should not be regarded merely as a direct source of plant-food, and that care must be taken to apply it only to soils which are fit to profit by it.

As regards the action on humus, it appears that carbonate of soda behaves very much like carbonate of potash ; and it is of interest to recall the fact that nearly fifty years ago it was proposed here in Massachusetts to make composts of peat and soda-ash.† There is of course, however, always an important advantage to be credited to wood-ashes and potashes, as compared with any sodium compound, in that the potash of the ashes is a true food of plants while soda is not. Mayer has seen tobacco-plants grow with noticeable luxuriance when manured with carbonate of soda. He found also that carbonate of soda and chloride of potassium used together were favorable for the growth of tobacco, and that millet grew decidedly better when the sodium carbonate was used than when it was not. Professor Johnson's experiments on the improvement of soil-nitrogen by alkalies have been cited in vol. I. of this Bulletin, p. 265. Compare also Bobierre's statement on p. 271. It is worthy of remark that the observation of Angus Smith,‡ to the effect that putrefaction is apt to set in when a soil rich in organic matter is wet with an alkaline solution and kept warm, is plainly in full accord with the more recent observations of mycologists who find that while the development of the bacteria which are concerned in putrefactive processes is hindered by acids, their growth is rapid in liquids that are slightly alkaline.

The significance of this first decay of organic matter, such as

* See "Nineteenth Report of the Secretary of Massachusetts Board of Agriculture," 1871, pp. 101, 103.

† S. L. Dana, "A Muck-Manual for Farmers," pp. 184–189.

‡ Cited in vol. I. p. 387, of this Bulletin.

occurs in the compost-heap as a preliminary step or preparation for nitrification proper, was clearly perceived by several of the earlier chemists at a time when the question of saltpetre-making was much discussed.   Many references to the subject will be found in the essays on saltpetre-making that are contained in the 11th volume of the "Mémoires des Savans Étrangèrs." Lorgna in particular (p. 174 of part I. and pp. 248, 249 of part II.), — in arguing that it might be possible to make nitre-beds succeed in the open air, especially during the first periods of the fermentation, and that the earth need not be put under cover until the time of the actual formation of nitre, — proposed to set aside a field having light, friable soil shaded by trees ; to manure it and sow upon it seeds of various plants.   When the plants had grown so that they were full of sap they were to be spaded under — just after rain, in order that they might putrify the more readily ; and the operations of sowing seeds and spading under plants were several times repeated.   Finally, when the soil was thoroughly impregnated with putrified vegetable matter, it was to be put under sheds ; since, as was urged, it is during the last term of the process of fermentation that a nitre-bed stands in greatest need of being protected from the weather.

The mixing of wood-ashes with the earth of nitre-beds was an act of a different order from the use of ashes in compost-heaps.   It depended primarily no doubt upon the power of the carbonate of potash in the ashes to react on nitrate of lime in the nitrous earth, with precipitation of carbonate of lime and formation of true salt-petre.   It is not probable that the ashes did much if any good by promoting the decay of refractory organic matter in this case as they would do in an agricultural compost-heap ; but by virtue of their alkalinity the ashes must sometimes have favored nitrification proper in the nitre-beds, as they doubtless often do in fields to which they have been applied as a fertilizer.   Boussingault has insisted on this point, and Schloesing and Muntz have shown that nitrification is rapid in presence of extremely weak solutions of the carbonates of potash and soda, although stronger solutions of these alkalies may hinder or even completely stop the action of the nitric ferment. Ordinarily, however, the alkalinity necessary for the nitre-beds was obtained by adding to them leached ashes or chalk, and it may be true that, in so far as mere nitrification is concerned, carbonate of lime (leached ashes) may do just as much or possibly more good than carbonate of potash (such as live ashes afford) ; for the solu-

tion of the lime carbonate in carbonic acid water that would naturally form in a nitre-bed is distinctly though feebly alkaline, and there would be no such risk of this solution becoming too strong as there might be if a source of carbonate of potash were at hand. The point is not without interest since it bears directly on the much-disputed question of the relative value in agriculture of leached and "live" ashes.· It is not improbable, for instance, that in some situations where the exciting of nitrification in a soil may ensure the success of a crop, an abundant dressing of leached ashes may do almost as much good as wood-ashes would have done. So too the singular endurance — i. e. the long-continued fertilizing action — exhibited by ashes in many localities probably depends in good part on nitrification which the ashes favor and support. It is noticeable that both live and leached ashes have been heartily recommended as applications for Indian corn, — the one in some localities and the other in other places; and although the success of this crop probably depends in great measure and generally on nitrification of the soil-nitrogen, it is not improbable that the first action on the soil-humus of the alkali in live ashes may be of importance in some cases; perhaps by preparing the humus for rapid nitrification, if for no other reason. Herein may perhaps lurk one difficulty as regards the question of estimating what the real value of potassium carbonate would be if it were taken by itself and used in comparison with other potash-salts. It is probable enough that wood-ashes may do several kinds of work while the powers of pure carbonate of potash may be less varied and those of the neutral potash-salts be more limited still.

C. — *Utility of mixtures of Stassfurt potash-salts and lime.*

From what has been said already of the alkali-lands of California, it is to be inferred that mixtures of chloride of potassium and lime must be useful additions to some kinds of soils, since when fitly placed such mixtures may work to improve the water-holding condition of the land and to make the soil-nitrogen available for crops. The last-named point has already been discussed to a certain extent in this Bulletin (vol. I. p. 391). It may readily be illustrated by referring to what is known of the reactions which occur when common salt and lime come in contact with one another in porous earth, and there is no lack of evidence to attest the significance of this reaction. Since the beginning of history considerable quantities of an impure carbonate of soda have been

brought into commerce from the so-called natron-ponds of Egypt, which are situated in the desert some thirty or forty miles from the Nile and not very far from the mouth of that river. The desert in this vicinity was at one time covered by the sea, and it is still charged with common salt as well as with carbonate of lime. Once a year, when the Nile is full, the desert soil is percolated by the river-water which dissolves out the sodium carbonate that has resulted from the reaction of the salt on the limestone and carries it forward to the depressions known as the natron-ponds, from which it is taken some months afterward when the Nile has fallen and the water in the ponds has had time to dry up. It was noticed long ago by Clouet [*] that if powdered chalk be mixed with sand that has been moistened with a solution of chloride of sodium, and the mixture be left in contact with the air, an efflorescence of carbonate of soda will soon appear on the surface of the sand. As Boussingault puts it : "Thus by the conjoint effect of capillarity and the carbonic acid of the atmosphere (or that in the pores of the soil), common salt in the conditions above mentioned undergoes by contact with chalk a partial decomposition, of which the result is carbonate of soda, — a salt, like carbonate of potash, most favorable to the growth of plants. Accordingly, in furnishing sea-salt to a soil sufficiently calcareous, we really enrich it with carbonate of soda. We moreover perceive that the same salt diffused through land devoid of carbonate of lime may not produce any fertilizing effect." So too Sir Humphrey Davy,[†] early in this century, remarked as follows in his lectures on agricultural chemistry : "In soapers' waste from the best manufactories there is scarcely a trace of (soluble) alkali. Lime moistened with sea-water affords more of this substance, and is said to have been used in some cases (by farmers) with more benefit than common lime." Girardin in France and Geubel in Germany [‡] have in like manner insisted that salt which has been applied as a manure often reacts on lime in the soil with formation of carbonate of soda which favors the growth of crops.

Reinders,[§] in his turn, in reporting his studies of the influence of

    [*] Boussingault's "Rural Economy," p. 336 of the New York edition of 1865.
    [†] "Elements of Agricultural Chemistry," p. 232 of the Philadelphia edition of 1821.
    [‡] Cited by Peters in "Stœckhardt's Chemische Ackersmann," 1861, **7.** pp. 32, 33. See also Heiden's "Düngerlehre," 1868, **2.** pp. 496, 617.
    [§] "Die landwirthschaftlichen Versuchs-Stationen," 1876, **19.** 197.

sea-water on soils, says : " When earth that has been soaked with sea-water dries out thoroughly it effloresces, and the same appearances may be seen on walls which have been built or plastered with lime that contained common salt.   This white " growth " may often be seen on the sea-strand in dry summer weather, and it is apt to be at its best several days after an exceptionally high tide. I collected a quantity of this white substance from several spots on the strand, taking care to get it as pure as possible, and found that it consisted in part of carbonate of soda.   Consequently carbonate of soda and chloride of calcium must have been formed from chloride of sodium and carbonate of lime under these conditions."

Here in Massachusetts, as long ago as 1839, Dr. S. L. Dana,* of Lowell, labored assiduously to diffuse a knowledge of the fact that useful manure may be made by treating peat with alkalies. He insisted in particular on the advantages that may be obtained by making compost with a mixture of lime and salt, whereby peat may be " cured " so that it can in some part replace dung ; or as we now know, so that some of its nitrogenous constituents may become available food for plants.   The efficacy of the methods prescribed by Dana manifestly depends on the presence of alkalies ; that is to say, in the case of the lime and salt, on the formation of small quantities of carbonate of soda, as has been explained already.†   It should be said that the teachings of Dr. Dana have had no little influence in this country.   The lime and salt mixture has been, at one time and another, freely used by American farmers in compost-making.   A good illustration of the estimation in which the mixture was held is afforded by the following citation from the " Sixteenth Report of the Secretary of the Massachusetts Board of Agriculture," 1868, p. 286.   The statement is there credited to Mr. E. L. Metcalf.   " We have used large quantities of wood-ashes — in fact all we can get — every year ; we also use lime and salt, which we consider invaluable on certain soils.   Properly prepared it is a powerful fertilizer and good for any crop.   In gardens and fields too rich in humus . . . it appears to change the chemical condition of the soil and give new life to the inert elements of fertility that are in the land."   The same writer speaks of using with advantage a mixture of leached ashes, salt, and plaster of Paris.

Mayer himself speaks of the weak alkaline reaction which is ob-

* See his " Muck-Manual for Farmers," Lowell, 1842, ch. VII.
† Compare this Bulletin, p. 392 of vol. I.

tained when carbonate of lime and neutral chlorides or sulphates react upon one another, and he has noticed in experiments on tobacco that a mixture of sulphate of potash and one third lime increased the luxuriancy of the development of his plants. He observed that a corresponding addition of sodium carbonate acted similarly, but that the effect of a larger amount of mere carbonate of lime was less favorable.

As for the compaction of the soil due to this formation of the soluble alkali, Mayer testifies to the greatly diminished porosity (durchlässigkeit) of earth to which a mixture of lime and chloride of potassium had been added, and he alludes to the manifest resemblances which subsist between this phenomenon and those presented by certain loamy soils observed by him that had been overflowed and soaked with sea-water. He cites moreover a number of instances, taken both from field-experiments and from farm-practice, where mixtures of lime and Stassfurt salts have given better crops than were obtained from either of the materials taken separately ; and the very fact, which he insists upon, that there are numerous exceptions to this rule goes to show that not every kind of land is suited by such mixtures. Whence it seems to be not unlikely that they may act indirectly as ameliorants, rather than directly as sources of plant-food. The fact that the Stassfurt salts have often been found to do good service on land that has been marled may here be brought to mind, as well as Mayer's suggestion that mixtures of low-grade Stassfurt salts and lime are probably preferable in many cases to the potash salts by themselves, even if they are of high grades.

Several different suggestions have been thrown out at one time and another in explanation of the apparent capriciousness of the action of mixtures of lime and Stassfurt salts, and it has been suggested by Wagner and others that such mixtures had better be applied to the land in the autumn, in order that any chloride of calcium that may be formed shall be washed away by the winter's rains. This view is supported by the results of Mayer's pot-experiments, which show that the presence of chloride of calcium was hurtful as regards the soils used by him. But if it be true that one merit of such mixtures consists in their power of alkalinity, it may possibly sometimes be best to apply them in the spring, care being taken of course to select such kinds of soils as may need the alkaline treatment or can bear it. It will be well meanwhile to remember Boussingault's suggestion that the power of common salt to

react upon lime when in presence of porous bodies may perhaps explain one class of cases in which salt has approved itself a useful manure. It is conceivable at all events that when salt is applied to soils of fit composition and contexture that contain carbonate of lime the above-mentioned reaction may occur, so that the land will really get a dressing of the soluble alkali (carbonate of soda) which is effective, as has been said, to promote the decay of humus, to bind the soil, and perhaps to disintegrate some useful mineral constituents of the soil. Indeed it is hardly possible to escape the conviction that there must be somewhere in the world soils whose fertility is promoted in this way; for we see in the alkali-deserts that the reaction between salt and lime does really occur in nature, the only trouble being that the reaction is commonly too strong for the purposes of agriculture — so much of the alkali being formed that vegetation, or at the least the texture of the soil, is destroyed by it. But since there is good reason to believe that small quantities of the alkali will conduce to fertility in certain cases, it is to be inferred that there must be some localities where the reaction occurs naturally in the proper degree. In saying this much I do not wish in the least to ignore the well-known fact that much harm may be done by saline fertilizers when they are put in improper places. Dr. Voelcker * has stated the matter well in connection with his experiments on the use of salt as a fertilizer. Writing for the climate of England he says : " As far as my experience goes I am more and more constrained to look upon all very soluble saline manures as rather dangerous agents ; for I have noticed over and over again the injury which these kinds of fertilizers produce in dry seasons, especially if they are applied rather late in spring. . . . Unless common salt or potash-salts can be applied to the land quite early in the spring I believe it would be better in nine seasons out of ten not to make any use of these very soluble matters, which require to be thoroughly washed into the soil if they are to benefit the crops for which they are used."

In speaking of loams that had been wet with sea-water, or to which lime and chloride of potassium had been added, Mayer is inclined to attribute the observed compaction of the earth to the presence of chloride of calcium ; and Reinders † dwells, in a somewhat similar spirit, on the puddling of loams by sea-water. He speaks of an overflowed loam as being " puddled, stiff, and out of

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* " Journal of the Royal Agricultural Society," 1870 (2), **6.** 397.

† " Die landwirthschaftlichen Versuchs-Stationen," 1876, **19.** 201.

condition (unbequem)," and argues that these effects are in some part due to the presence of common salt. From the context, however, it would appear that, unlike Hilgard (see above, p. 345), he found no special difficulty in tilling this soil, — *i. e.* making a seed-bed whose mechanical condition seemed to be favorable for the growth of plants. There is naturally no need to say here that the presence of an undue proportion of chloride of sodium or other soluble saline matter in the soil will hinder seeds from germinating and prevent many kinds of plants from growing. Reinders found by experiments when sea-water was made to flow gently upward into loose, moist loam that the earth settled or shrunk upon itself to a marked degree, and that the shrinkage was appreciably increased when the wet earth was stirred. Clayey soils shrunk more and faster when shaken up with sea-water than when shaken with distilled water, but the effect was much less marked with sandy loams. He observes that practical men have remarked upon the facts that where stubble-fields have been overflowed by the sea the stubble seems as if it had been lifted upward, and that ploughed land looks as if it had been subjected to pressure.

Reinders found furthermore that the water-holding power of loams that had been soaked with sea-water was perceptibly diminished. In three cases out of four more water was retained in the pores of the natural loams than could be held by them immediately after they had been drenched with sea-water. Yet it is a matter of practical experience in Holland that soils which have been overflowed by sea-water tend to remain moist for a long time. In attesting this fact Reinders seeks to explain it by assuming the presence of hygroscopic salts ; viz. chloride of calcium and chloride of magnesium.* He remarks, however, incidentally, that the structure of the earth examined by him in this particular experiment underwent changes and became cloddy (broecklich) and harsh ; and in another paragraph, when describing land that has been overflowed, he says : " The soil silts together and remains moist for

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* As had been done before by Peters in "Stœckhardt's Chemische Ackersmann," 1861, **7.** 29, and again in his report on Grouven's experiments in the " Jahresberichte der Agrikultur-Chemie," 1865, **8.** 289, 290. It is to be remarked that in all these instances the soil was kept moist in some way as a result of the application of chloride of potassium or of sodium. So it was in the cases noticed by Fleck (" Hoffmann's Jahresbericht," 1859-1860, **2.** 256), who attributed the observed dampness of his potato-fields that had been dressed with Stassfurt minerals to absorption of moisture by the saline constituents of the fertilizer.

a long while. Sometimes salt is seen to effloresce upon the land."
And yet again he dwells on the fact that land freshly embanked
from the sea can often be cultivated immediately with success ; so
that the question would still seem to be open and well worthy of
consideration, viz. whether some part of the moisture observed in
such soils may not be due to changes of texture brought about by
the presence of carbonate of soda at a secondary stage when, as
Reinders himself has shown, this compound has had time to form
within the soil. In experiments where perforated boxes of loam
were overflowed with sea-water and then sunk in a garden to the
level of the surrounding soil, it appeared that the amount of chlo-
rine fell in the course of two years from 0.21% to 0.008%, and that
during the second year the texture of the earth became loose, even
beneath the surface, in marked contrast to its previous condition ;
that is to say, the loam finally returned to its normal state.

Of course some portion of the puddling-effect produced by sea-
water would be brought about by any water, even the freshest, in
so far as there was any stirring action in connection with the flow-
age, and in so far as plastic particles of mud were silted into or
upon the soil. But it is evident enough that sea-water has of itself
a very considerable and peculiar influence upon the tilth of soils,
as Van Bemmelen and other Hollanders have insisted, though it is
none the less plain that the changes of mechanical condition pro-
duced by sea-water of itself are distinctly different from those pro-
duced by the alkalies. A good part of the binding effects noticed
by Reinders are probably nothing more than particular instances
of a general fact that has long been known, viz. that common salt
— as well as lime and its compounds and various other soluble sa-
line or mineral matters — have power to cause finely divided moist
particles of matter to cohere into larger masses. This fact is fa-
miliarly shown by stirring a solution of salt into muddy water, —
as, for example, turbid clay-water taken from a mud-puddle, which
may quickly be " settled " in this way. Stupendous examples of
this phenomenon occur in Nature, where muddy rivers flowing into
the sea soon become clear because the suspended matter is precip-
itated by the action of the salt. But this coalescence or granula-
tion produced by salt is a very different thing from the increased
stickiness or plasticity that is brought about by mixing small quan-
tities of either of the soluble alkalies with clay or other fictile earth.
Indeed the action of salt may be regarded as antagonistic to plas-
ticity, and there are cases on record taken from agricultural prac-

tice where heavy dressings of common salt that had been applied as a fertilizer distinguished themselves by rendering sticky soils mellow and crumbly.* Professor Atwater,† from the results of numerous farm-experiments with fertilizers, that were made under his guidance, was persuaded that on heavy clays that naturally contain a good deal of potash the good effects produced by chloride of potassium must have been due in good part to its indirect action in loosening or otherwise improving the mechanical condition of the soil by coagulating the clay or by rendering other kinds of plant-food available.

It would be an interesting point to determine by observation and experiment in field-practice how much the peculiar binding powers of common salt (or of chloride of calcium) and of the alkalies may hinder or help one the other; and it would seem to be not wholly improbable that the Dutch chemists and farmers may have failed to distinguish between two kinds of binding effects: the one primary, i. e. due directly to common salt; the other secondary, i. e. caused by a product (carbonate of soda) which has resulted from the decomposition of the salt. It is of interest to note that Voelcker,‡ in describing his experiments with common salt (and Stassfurt salts) on mangolds (and other crops), relates that the salt was often found to be useful on light, sandy soils, but not on clays. It may be noted also that, on light land, salt tended to develop the leaves of the beet plants.

Naturally enough it is extremely difficult, in the case of chemicals like common salt or chloride of potassium, to determine just what their mode of action is in any given instance; for they may, and undoubtedly do, act in several different ways according to circumstances. How shall we explain, for example, the physiological effect noted by Nessler,§ who observed not only that tobacco manured with salt was tougher and more pliant than that from soil which got no salt, but that the quality of hemp was improved in that the fibre could be spun with less waste than usual. As the spinners said, the salt-grown hemp was "greasier." Or what shall

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* See, for example, "Hoffmann's Jahresbericht der Agrikultur-Chemie," 1861–1862, **4.** pp. 269, 270.

† "Report of Work of the Agricultural Experiment-Station," Middletown, Conn., 1877–1878, pp. 91, 106.

‡ Compare, for example, "Journal of the Royal Agricultural Society," 1864, **25.** 240, 389.

§ "Jahresbericht der Agrikultur-Chemie," 1873–74, **16–17.** (3d part) p. 79.

justify the English custom of adding salt to grain-fields to hinder the growth of straw, *i. e.* to prevent the leafy part of the crop from becoming too rank. All that is really known thus far is the empirical fact that the growth of some plants (such as wheat) is hindered by saline fertilizers on soils where the growth of other plants (like beets and cabbages) is promoted even by tolerably heavy dressings of them.* It is not impossible that heavy dressings of the chlorides of sodium or potassium may exert a germicide action in some cases — whether for harm or good depending naturally on circumstances in each particular instance. It is certain, at all events, that in the old European system of making saltpetre in beds, the presence of more than a small proportion of salt in the earth was found to distinctly hinder nitrification.† Some such action as this may have been the original motive of the old Swiss practice of adding salt to dung-liquor to improve it. As everybody knows, salt has often been employed in heavy doses for clearing land from weeds, worms, and insects.

D. — *Potassic manures are specially acceptable to leguminous crops.*

Perhaps nowhere else in the world has the merit of potash as a manure for clover been more clearly and generally recognized than in this country. Indeed it has been accepted as an article of faith by many generations of New England farmers that ashes will " bring in " clover, as a matter of course, when applied to pastures or mowing-fields — a fact which has been illustrated and, so to say, methodized in recent years by Messrs. Lawes and Gilbert in their well-known experiments on the effects of different manures on the composition of the mixed herbage of meadow-land. Forty or fifty years ago, when red clover was frequently or even habitually grown in the immediate vicinity of Boston in admixture with Timothy as a source of hay, it was a matter of common belief and experience that the crop would be certain to succeed if only some wood-ashes could be procured to sow with the clover-seed. It is true that clover is no longer grown hereabouts, and that no pains are taken to favor it, though there is small reason to believe that this plant has been discarded by our farmers because they are unable to produce it.‡ But

* Compare J. Lehmann, "Hoffmann's Jahresbericht der Agrikultur-Chemie," 1862–63, **5.** 247.

† See "Recueil des Mémoires sur la Formation du Saltpêtre, in Mémoires des Savans Étrangers," 1786, vol. XI. *passim.*

‡ The reasons why clover is no longer grown around Boston are no doubt

there is an abundance of clover in the mowing-fields of the fertile region not far from Portsmouth, N. H., lying back of Rye Beach and other smaller beaches, whence the farmers procure an abundance of kelp and rock-weed and various other sea-plants that are useful as manures. Thanks to the saline constituents of the sea-manure, the soil of that region still receives, as it has for generations, an abundance of potash compounds ; and one result of the application is — what is very remarkable in this part of New England — that red clover grows freely and,. so to say, continuously. Far from " running out" in the course of three or four years after sowing, the clover there tends to persist and to permanently occupy a considerable share of space in the mowing-fields. Similar results may be seen in other parts of New England that are similarly fa-

various. But perhaps chief among them is the comparative difficulty of harvesting clover-hay with the machines which are now so universally used in New England for mowing, tedding and raking grass, and which were invented and adapted for that particular purpose and no other. In order to cure clover-hay in first-rate condition the process of drying must not be hurried; nice manipulation is in some sort essential lest the leaves be lost by crumbling before the stalks are dry. In case a standing crop of clover should lodge it would not be easy to cut it with the mowing-machine, while the cost of mowing it by hand would be so large as to preclude perhaps all chance of profit. In other words, the fact that clover does not admit of being harvested with that rapidity which has become habitual in this locality in respect to grass tends to make our farmers impatient of delays such as the curing of clover-hay would naturally occasion. Another point to be noticed is that — together with the machines — horses have been procured by the farmers in order to work the machines. These animals have in fact been substituted for oxen on numberless farms in recent years ; and since clean, bright, dustless hay is thought to be specially desirable for horses there is a very decided tendency not to sow clover in fields which are devoted to the growing of hay for horses. The same remark will apply to the enormous quantities of hay that is grown to be sold for the use of horses in towns and cities. Not but that hay which contains a just proportion of clover may be excellent food for horses when it has been cured perfectly, but that there is a general risk in using clover-hay because of its liability to suffer more or less from fermentations, i. e. from the action of fungi with results which are injurious to the health of the animals. As the practical horseman puts it: " Clover is liable to ' get touched ' in the making; then the hay is ' dusty,' and it makes horses cough." It is presumable that neat cattle are less sensitive to mouldy hay than horses anyway, and certain that their capacious organs of digestion are somewhat better fitted than those of horses to deal with the bulky and comparatively-speaking indigestible fibre of the clover-stalks. As a friend once said to me, if by any chance the practice of soiling cows should ever become general in New England, clover will probably be grown again hereabouts as it was in the days that have gone by.

vored, as well as in some localities where the soils seem to have been derived from granitic rocks. It is noticeable also in many places on the south shore of Massachusetts Bay, and in the so-called Old Colony, that red clover prospers and tends to grow naturally on farms where hay from salt marshes is or has been used for feeding and bedding cattle. It is noteworthy that the effect of the sea-manure, while pointing clearly to the merit of potash, must depend upon saline compounds of this substance, *i. e.* it goes to show that other compounds of potash beside the carbonate which is found in ashes may greatly promote the growth of clover. Of course the nitrogenous and the phosphatic constituents of the sea-weeds would help the growth of the clover as they would that of another crop. So too the alkaline quality of the wood-ashes previously mentioned was doubtless advantageous in helping to bring the humus of the soil into fit condition for the clover to feed upon. It would consequently not be right to expect that a mere neutral salt, such as chloride of potassium, will generally serve so useful a purpose on clover as either ashes or sea-manure, though it may sometimes do an equal amount of good on soils capable of supplying assimilable nitrogen and phosphates. There are in fact upon record the results of numerous experiments in which the use of one or another of the Stassfurt salts has greatly increased the growth of clover. For example, Mr. Sedgwick,* of Connecticut, having applied a large quantity of low-grade Stassfurt salt to oats without benefit, obtained from the land next year a remarkably fine crop of clover. Mr. Farrall,† in his prize essay on the agriculture of the Scotch counties of Edinburgh and Linlithgow, says of the region about Edinburgh : " Clover-sickness is experienced in some cases and is undoubtedly owing to want of potash. . . . A friend applies kainit or potash-salts where the land was formerly clover-sick ; now he raises splendid crops of clovers which are never thrown out in the winter months as they were before potash was used."

No doubt the so-called clover-sickness of land may be due to one cause in one locality and to some other cause in another. But it seems to be tolerably well made out that the trouble may frequently be alleviated by applying potassic fertilizers.

The great favor with which gypsum was regarded, a century or

* "Eleventh Report of the Connecticut Board of Agriculture," 1877–78, p. 369.

† "Transactions of the Highland and Agricultural Society," 1877 (4), 9. 23.

more ago; as a specific for clover points to the same conclusion as the foregoing results, inasmuch as there is good reason to believe that gypsum acts chiefly by setting free potash from certain silicates in the soil which had held it in rather firm combination. It has often been remarked that even superphosphate of lime may occasionally do a certain amount of good in the same way by virtue of the gypsum which is naturally contained admixed with it. There is nothing of novelty in the foregoing statements; the facts set forth in them have long been familiarly known. Indeed the German chemist, Grouven,* long since expressed his belief that the so-called clover-sickness of land might be due to a lack of potash; and this view has often been taught, subject of course to limitations and exceptions. Dr. Gilbert,† in his South Kensington lectures, distinctly formulates the rule derived from the field-experiments of Mr. Lawes and himself, that potassic manures increase in a striking degree the growth of crops of the leguminous family (peas, beans, clover, etc.), as well as the amount of nitrogen they assimilate from a given area, although such manures give comparatively little increase when applied to grain-crops.

Mayer admits that chloride of potassium commonly produces a considerable increase of crop when applied to clover, but he urges that in his own experiments he found it inferior to the sulphate. He found moreover in his experience that an application of a mixture of lime and chloride of potassium to clover just before sowing was highly disadvantageous. He argues that the chloride is by no means the best form in which to employ potash-compounds upon clover. In experiments on clover made on a loamy soil that was somewhat sour, and poor as to potash, lime, and magnesia, — and which was reputed to be tired of clover, — he got good crops by manuring either with sulphate of potash, or with lime, or with a mixture of the two; but, as was just now said, the crops obtained from chloride of potassium, or from mixtures of it and lime, were poor. He speaks of the superiority of the sulphate to the chloride as being specially remarkable, and argues in favor of using the sulphate, even of low grades, instead of the chloride for this crop.

E. — *Neutral potash-salts, when applied by themselves, sometimes notably increase the yield of arable crops.*

It has often been remarked in Europe that the results obtained

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* "Hoffmann's Jahresbericht der Agrikultur-Chemie," 1862, **5.** 140.

† "American Journal of Science," 1877 (8), **13.** 30.

by the use of the Stassfurt potash-salts have been extremely variable and uncertain. Indeed, it has been asserted by several writers that it is only on sour mowing-fields and on moors that have been reclaimed by the method of covering with gravel that the Stassfurt salts have approved themselves really profitable. Under the ordinary conditions of farming-practice the use of them is said not to have brought remunerative returns in the majority of cases, while in some instances they have been found to be actually hurtful. Mayer has expressed himself somewhat as follows : It may be admitted, he says, as a fact that is generally known, that the Stassfurt salts — the cheapest form of potassic fertilizers, and the kind which has been most commonly applied hitherto — have failed to yield results that were commensurate with the expectations, even when they were applied to soils which from the mode of cropping or from the results of chemical analysis were supposed to be relatively poor in potash. He urges that the question is how to explain this fact. I have myself urged, in another connection,* that one conspicuous reason why potash compounds are held in so little esteem by most European farmers will be found in the time-honored practice which prevails there of returning large quantities of straw to the land, and in that way supplying in abundance the potash which is contained in the straw. While upholding in general the superiority of wood-ashes, or of composts made of pot-ashes, on account of their power to supply nitrogenous as well as potassic food, I have dwelt also on some of the good results that were obtained in this country long ago from the use of potash-compounds other than the carbonate as it exists in wood-ashes. Professor Atwater † likewise has cited numerous instances where muriate of potash has done good service even when used by itself. On some poor soils where neither nitrate of soda nor superphosphate of lime, whether used separately or together, brought crops of potatoes or Indian corn, the muriate of potash did excellent service — every plot that had been dressed with this substance having given a large yield, while no crops, or as good as none, were obtained from the competing plots that had not received any of the potash-salt. He remarks that the benefit derivable from the muriate was apt to be striking whenever there was any benefit at all. In some of his cases it appeared that the potash-salt, when used

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* "Bulletin of the Bussey Institution," 1874, **1.** 160.

† "Report of Work of the Agricultural Experiment-Station at Middletown, Conn.," 1877-78, p. 82 *et seq.*

upon Indian corn, had repaid its cost more than tenfold. Upon potatoes in particular he found that the muriate of potash generally did good service, — the yield of tubers having been increased by it in nearly every experiment.* . It was noticeable, however, that when used upon Indian corn the muriate of potash frequently failed to show much effect. In these experiments nitrate of soda used by itself seldom produced much effect, while plaster of Paris, though generally of little avail, sometimes showed marked results. Superphosphate of lime by itself often did good service. There were a number of cases moreover where neither the nitrogenous nor the phosphatic nor the potassic manures were particularly useful. Mixtures of the three kinds of fertilizers brought by far the largest average crops, and they were considerably better than those got from farm-manures. But the most profitable fertilizers were the partial ones, which fitted the demands of the special cases. Sometimes it was the plain superphosphate that gave the best return, sometimes the chloride of potassium, and sometimes a mixture of the two.

As the average of twenty-six experiments with maize, chloride of potassium (that contained 50% of K_2O), used at the rate of 200 lbs. to the acre, gave an increase of 8.7 bushels of shelled corn over "no manure," while superphosphate (of 16% P_2O_5), used at the rate of 300 lbs., gave an increase of 8.9 bushels, and nitrate of soda (of 16% N), used at the rate of 200 lbs., gave 5.8. The corresponding averages drawn from nine experiments with potatoes were respectively 33.7, 24.6, and 4.3 bushels. As regards the kinds of soil most benefitted by the chloride of potassium, Professor Atwater says that on heavy (clayey) soils of the poorer classes it seemed to have a better effect than on the poor soils of lighter character, — whence his conclusion, already cited, that the muriate had a favorable action in loosening heavy soils by precipitating the gelatinous clay.

It may here be remarked that Mayer has computed from the results of forty-six field-experiments with chloride of potassium (of 50% K_2O) that 1 kilogram of this material has given an average increase of 2½ kilos. of sugar-beets (380 kilos. of K Cl having produced an average increase of 914 kilos. beets to the hectare of

* A record of some interesting experiments with Stassfurt fertilizers on potatoes, which consist well with those reported by Professor Atwater, will be found in Lawson's "Ten Years of Gentleman Farming," London, 1874, pp. 365, 371, 891; also in "Transactions of the Highland and Agricultural Society for 1873."

land); thirty-two experiments with sulphate of potash, of the higher grades, gave an increase of 5½ kilos. of beets for 1 kilo. of the sulphate ; from twenty-one experiments with wood-ashes, used either by themselves or with superphosphate, it appeared that 1 kilo. of the ashes had produced an increase of 2.7 kilos. of beets,* while from several hundred experiments with superphosphates it appeared that 1 kilo. of the material gave an increase of 5 kilos. of beets.   For potatoes he computes, from twenty experiments, that 1 kilo. of chloride of potassium produced nearly 3½ kilos. increase ; and a kilo. of sulphate of potash about as much or rather more than the chloride.   For grain the results were much less favorable.   In spite of several brilliant exceptions in the case of oats, it appeared that the increase of grain on fields manured with Stassfurt salts had hardly been equal on the average to the weight of the fertilizer employed.

A grave objection may of course be urged to averages such as these, in that they do not give just prominence to results that are positively favorable.   The figures, as given, actually conceal the conspicuous merit which the fertilizer has exhibited in certain cases.   The question, as presented in this article, is not at all whether potassium-salts are useful fertilizers in all cases, — that question has long since been answered in the negative.   The problem now awaiting the verdict of practical experience is, to what soils and in what forms had potassic fertilizers best be applied?   It is hardly necessary to say that there are numerous European experiments made with Stassfurt salts which show very favorable results, or to urge that the use of these fertilizers has been frequently commended.   The following citation from so competent an observer as Dr. Voelcker † expresses a conviction which he arrived at after much experience and observation.   "On reviewing this report, it will be found that in every trial in which potash-salts (kainit) were applied to root-crops, either alone or in conjunction with other fertilizing matters, they materially increased the crops. Considering the number of trustworthy experiments now on record, all affording distinct evidence of the utility of potash-salts as manuring constituents of a turnip, potato, or mangold manure, intended to be used upon light land, there can be little doubt of the

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* As Mayer remarks (p. 112, note), this result must be regarded as comparatively-speaking high, in view of the relatively small amount of potash in a single-kilogram of ashes.

† "Journal of the Royal Agricultural Society," 1871 (2), 7. 382, 386.

more abundant use which these salts will find in British agriculture.
. . . It follows clearly from the results of the experiments on potatoes here recorded, and of those previously published by me, that potash-salts materially increase the produce of potatoes, and that they are very useful constituents in a potato-manure — at all events upon light land."

More than a century ago Home,* of Edinburgh, observed that the application of sulphate of potash had a beneficial effect on vegetation, and Sprengel, in his day, reported similar experiences from Germany ; but the salt was then too costly to permit its coming into use as a manure.

In vol. I. p. 386 of this Bulletin I have already alluded to the use at Sandwich in this State, between the years 1820 and 1840, of sulphate of potash, such as is obtained in the refining of pearl-ash for glassmakers.† It was found to give excellent results when applied admixed with loam as a top-dressing to grass, rye, corn, and oats.   In this case it might be argued, with some show of justice, that the presence of a small proportion of carbonate of potash that remained clinging to the sulphate may have increased the fertilizing effect of the material.   Perhaps it might be worth the while in some localities to try field-experiments with chloride of potassium (or with the sulphate) with which carbonate of potash (potashes) had been mixed in various proportions, in order to test the merit of such admixture in comparison with the mixtures of lime and potash-salts which have been a good deal used abroad.   It would undoubtedly be well also to experiment with artificial ashes, i. e. with mixtures of carbonate of potash and of lime that has been slacked with water and afterward carbonated by exposure to the air, with the view of finding which among several potassic fertilizers may be best fitted for a given field or farm.

Pure sulphate of potash, such as is made for medicinal purposes, has sometimes been used in this country, to my knowledge, in conjunction with nitrogenous and phosphatic fertilizers, for manuring tobacco.   The motive in using the comparatively costly refined product was to avoid any contamination with chlorides, which are known to injure the combustibility of the tobacco leaf.

The general impression that sulphate of potash is a better fertilizer than chloride of potassium seems on the whole to be founded

* Cited by J. F. W. Johnston, in his "Lectures on the Application of Chemistry to Agriculture," New York, p. 830.

† "Colman's Fourth Report of the Agriculture of Massachusetts," p. 344.

in truth ; but it is a little remarkable that the notion should have gained such currency as it has, in view of the fact that most potassic fertilizers sold as "sulphates" are really highly charged with chlorides, and are presumably subject to all the objections which would apply to the chlorides properly so called. Mayer remarks, however, that the change from chlorides to sulphates marks an epoch in the history of the sale of fertilizers at Stassfurt, — kainit being more and more used in recent years, instead of carnallite as formerly. In'pot-experiments, made for the purpose of comparing chloride and sulphate of potash (the pure salts being used in both cases), Mayer got decidedly better crops of clover, millet, and tobacco with the sulphate ; but in the case of grain there was no important difference between the two results. The soils used in these experiments were poor, and they were for the most part dressed with phosphatic and nitrogenous fertilizers in addition to the potash-salt. The fact, repeatedly verified, that the potash in chloride of potassium is not arrested, i. e. "fixed," so speedily by the earth as potash which is applied in the form of sulphate would seem to show that the chloride might sometimes be specially useful as a means of distributing potash throughout a soil that happens to be pretty thoroughly exhausted of this particular form of plant-food ; but, as has been intimated above, the substances ordinarily sold nowadays as sulphate of potash are abundantly able to serve this purpose, thanks to the chlorides that are contained in them. They are doubtless on this account better suited for such work than pure sulphate of potash would be.

As bearing on the use of sulphate of potash, it is worthy of record that some of our farmers were subjected to serious damage and annoyance a few years since through having put upon their fields an acid product which had been sold to them either as "sulphate of potash," or in disguise as an ingredient of some one of the so-called formula fertilizers. The substance in question was the sesquisulphate of potash, which results from the making of muriatic acid by distilling Stassfurt muriate of potash with sulphuric acid, — a process of manufacture which, as I urged some years since,[*] is clearly indicated as a proper one for the American seaboard states. But it is in some sort a necessity in this process of manufacture that an excess of sulphuric acid shall be used, over and above what would be necessary for converting the chloride into a neutral sulphate, in order that the residual "cake" may melt read-

ily in the retort, so that it can be drawn off in the fluid condition when the distillation is finished.   By roasting the cake in due course it is no very difficult matter to drive off the excess of sulphuric acid and obtain a neutral sulphate of potash eminently proper for agricultural use.   The excess of acidity might have been mitigated withal by mixing the cake with bone-black or with leached ashes, or by using the material on land that had recently been limed.   But, as was just intimated, certain manufacturers neglected at one time to roast their cake, and they sold the acid, corrosive product to be used directly as a manure, whereby no little harm was done through the destruction of seeds and young plants with which the substance came in contact.   My attention was called to one case in particular, where a crop of tobacco was checked and practically spoiled when the young plants were transplanted into land that had been unwittingly dressed with this material.   No doubt this acid sulphate might be used with advantage in certain cases, as an ephemeral agent of destruction, i. e. for cleansing land that is overrun with weeds or infested with insects or worms ; and a solution of it might be used for composting weeds, with the view of killing their seeds.   But the farmer needs to know what the material really is, so that he may either avoid it or use it with due care.   It is manifestly unfit for general use, and should never have been sold as " a manure."

The sensitiveness of many plants to acids, as illustrated by this example, and by numerous instances that are on record where the soluble phosphoric acid in superphosphates, having failed to be speedily precipitated in the earth, has done the crops more harm than good, may perhaps have some bearing even on the use of the neutral potash-salts.   For example, in case chloride of potassium were added to a soil that was not sufficiently charged with basic constituents, injury might perhaps be done to the crop by the chlorine in the potash-salt ; for, as is well known from experiments made by way of water-culture, plants can take the potassium from this salt much faster and in much larger quantity than they can take the chlorine, so that the latter, or more properly speaking chlorhydric acid, may actually be set free by the action of plant-roots.   In a properly constituted soil there would naturally be present an abundance of basic matters, with which the chlorine would combine, so that the crop would be left unscathed.   But harm might be done if these constituents were absent.   Possibly the presence of carbonate of lime in the soil may be a safeguard in

this sense, and it is not unlikely that some of the less insoluble hydrous silicates may serve the purpose well. It is not wholly impossible that the absence of such things from some soils may be one reason why chloride of potassium is thought to be a capricious manure. It is possible moreover that this matter of acidity may furnish the true explanation of the capricious and uncertain action of nitrate of ammonia,[*] when used as a source of plant-food in experiments made by way of sand-culture. As is well known, nitrate of ammonia readily parts with some of its ammonia and acquires an acid reaction. I have noticed recently that Davy,[†] in his time, was surprised to find that solutions of nitrate of ammonia did not answer so good a purpose for watering plants as solutions of the carbonate and the chloride. He says : " The plants watered with solution of nitrate of ammonia did not grow better than those watered with rain-water. The solution reddened litmus-paper, and probably the free acid exerted a prejudicial effect and interfered with the result."

Mayer has argued with considerable force that even for farm-practice those salts of the strong mineral acids from which plants assimilate the basic constituent more rapidly than they assimilate the acid are in general less useful manures than salts of weaker acids, or than those from which the plants can take either the acid or the base indifferently. He has even propounded the hypothesis [‡] that, inasmuch as the proportion which subsists between bases and acids in the ash-ingredients of plants are very different from the proportions between base and acid which obtain in the Stassfurt salts (*i. e.* in the chloride and the sulphate of potash), these substances are of comparatively small use as manures because of the difficulties which plants must necessarily encounter in trying to assimilate food from them. It may here be said that the marked inferiority as a fertilizer of chloride of ammonium to the other ammonia-salts, — as attested by wide experience and much experimentation, — bears directly on the alleged demerit of chloride of potassium. The point has been forcibly presented by Mayer. By neither of these compounds, as he argues, is food offered to plants in " a proper chemical form."

It has been repeatedly noticed in Europe, and urged as one

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[*] As noticed by Hellriegel and by myself. See Bussey Bulletin, **1.** 283.

[†] " Elements of Agricultural Chemistry," p. 231.

[‡] Here given in brief, without the careful explanations and qualifications which will be found in the original paper.

argument against the use of Stassfurt salts, that chlorides (whether of potassium or sodium) are liable to injure the quality of beet-juice, the combustibility of tobacco leaves, and the mealiness of potatoes. As regards tobacco, the same conclusion has been reached in this country; but with respect to potatoes the accounts in our agricultural papers are somewhat conflicting, and the general inference seems to be that, while there is undoubtedly a considerable risk of harm, the quality of the tubers is not so universally liable to suffer from this cause as has sometimes been supposed. In so far as regards mere increase of crop, it is in evidence that the potato has shown itself to be less sensitive to harm from moderate doses of chloride of potassium, and better able to profit by this fertilizer, than several other plants. As bearing on the amount of injury which extreme doses of chlorides may inflict, I cite the following paragraph from Pallas's "Travels in Siberia." * Writing in 1769, of the environs of Gourief and the variety of saline plants found there, he says: "It would hardly be believed that vegetables could succeed in such a soil. The commandant has a garden in which grow melons, cucumbers, beets, radishes, cabbages, kohl-rabi, and parsley. These plants succeed very well. But tobacco, celery, cauliflower, potatoes, and water-melons do not succeed. They have tried planting selected seeds of the watermelon, but the fruit obtained is very small and of very poor quality. This result is the more surprising, since the earth is moist and other melons and calabashes flourish marvellously."

As would naturally be expected, nitrate of potash has approved itself a powerful fertilizer in many instances. No doubt it would be widely used in agriculture but for the high price which it commands on account of the uses for which it is indispensably necessary in the arts. In this regard it would be hard to find a truer or more sensible statement than the following which was written nearly half a century ago by Mr. Phinney,† of Lexington, one of the most distinguished farmers of his day: "My experiments with saltpetre as a manure have satisfied me of the inexpediency of using it for that purpose. In the spring of 1839 I purchased 400 lbs. for which I paid $8 per cwt. I tried it upon wheat, rye, and grass. 50 lbs. to the acre on wheat and rye had no perceptible effect, and on grass but very little. 100 lbs. to the acre occasioned a very considerable increase of straw and grain, both in wheat and

* Pallas, "Voyages," 2. 361.
† Colman's "Fourth Report of the Agriculture of Massachusetts," p. 334.

rye as well as in grass. But had I expended an equal outlay in compost made from peat-mud and stable-manure, or peat-mud and ashes, I have no doubt the immediate crop would have been more benefited and the land have received more permanent improvement. I have in one instance seen very striking effects produced by the use of saltpetre upon a light sandy soil, but the quantity used I could not learn any further than that it was much greater than the quantity to the acre used by me."

I have been assured, however, by Mr. J. H. Adams that in spite of its high cost he has found nitrate of potash a profitable manure in certain cases where the money value of a crop is large and the quality of the crop a matter of paramount importance — as in the production of high-grade tobacco,* for example. He tells me that he has grown super-excellent potatoes also, for table use, by means of nitrate of potash. It is worthy of enquiry, however, since the motive in both these instances is manifestly a wish to avoid the hurtful effects of chlorides, whether a mixture of sulphate of potash and nitrate of soda, of exceptionally high grades, might not answer the same purpose as nitrate of potash and at less cost. Mayer admits that brilliant results have been obtained by the use of nitrate of potash used as a manure, and he remarks (p. 129) that in Holland it has been found to be particularly useful in the cultivation of flower-bulbs, which are commonly grown in sandy soils. He suggests that the nitrate might probably be profitably employed for manuring flax also, and perhaps other crops that are cultivated in an extremely intensive manner. Reports of good results obtained by the use of saltpetre-waste will be found in Colman's " Fourth Report of the Agriculture of Massachusetts," pp. 335–339.

F. — *Certain forms of silicate and humate of potash have approved themselves useful manures.*

In speaking of what is really known with regard to potassic fertilizers, Mayer urges that it is certain that plants can readily put to profit the potash which is contained in some of the less refractory silicates that are found naturally in fertile soils. This view is manifestly supported by the extended experience of New Jersey farmers with their green-sand marls, accounts of which have repeatedly been written — notably by Professor George H. Cook (Director of the New Jersey State Agricultural Experiment-Sta-

* Mayer makes a similar remark on p. 348 of his memoir.

tion), in his reports as Geologist of New Jersey and as Secretary
of the New Jersey State Board of Agriculture.   It is borne out
furthermore by what is known of the use of palagonite and other
forms of volcanic tufa in several localities.   The green sand of
New Jersey is said to be specially remarkable because of the per-
manent improvement produced on many of the soils to which it has
been applied.   Mayer argues moreover that in certain cases, es-
pecially when sandy soils are subjected to high culture, humus rich
in potash is clearly indicated as a proper fertilizer — a conclusion
which had been reached, in some part, by many New England far-
mers of an earlier generation, as evidenced by the estimation in
which they held ashes-compost as an application for light, leachy
loams.   He is inclined, indeed, to believe that the potassic manures
of the future may perhaps be restricted to silicates, humate, and
nitrate.   But it is plain that this view does not duly allow for
varying conditions as to soils and situations, and that by hold-
ing too strongly to it a variety of useful powers and purposes
which appertain to the carbonate, the chloride, and the sulphate
of potash might be lost sight of; namely, their capacity to enliven
the nitrogen of humus, to bind light loams, to improve the tilth of
clays, and to feed leguminous plants, — as well as some kinds of
hoed crops on poor lands.   With regard to the point last named,
Mayer commends Heiden's plan of applying potassic fertilizers in-
directly; the idea being simply to use crude Stassfurt salts on
pastures, or to apply them to clover, and to regard the dung of the
cattle which have consumed the forage as a potassic manure spe-
cially applicable to crops such as beets or potatoes which need
potash, but which, for one reason or another, may not be able to
bear the Stassfurt minerals as well as clover can.

No. 32. — *Facts gathered by observation and experience relating to the White Pine (Pinus Strobus L.)* By EDMUND HERSEY, Superintendent of the Bussey Farm.

PART I. GROWTH OF THE TREE.

As a timber tree the white pine possesses more good qualities than any other tree that is a native of Massachusetts.

First, it is easy to grow it from the seed or transplant it when young.

Second, it will grow on a light sandy soil or on a peat meadow.

Third, on an ordinary soil the growth is quite rapid, making in thirty-five years from the seed a tree large enough to be sawed with profit into box-boards, or coarse lumber.

Fourth, it makes lumber that can be used to advantage for a great variety of purposes.

When a pine forest is to be grown from the seed, an effort should be made to secure seed that is new and taken from the cone but a few days before the time it is wanted for planting.

The cones containing the seeds begin to grow in June, and when of the size of the end of one's finger they stop growing until the following year, when during the summer they grow to full size and perfect their seeds early in September ; the first frost severe enough to kill squash-vines opens the cones and the seeds drop out ; they are about the size of a parsnip seed, are very light in weight, and having a little wing on them, they float along through the air in a slightly downward direction, reaching the ground sometimes twenty rods from the parent tree, but more frequently not more than from one to five rods. Soon after reaching the earth the little wing separates from the seed, and if the seed is to germinate it becomes partially or wholly covered with earth by a heavy rain, or by the pressure of the foot of a passing animal, or the falling leaves may furnish sufficient protection to preserve its vitality. When nature is permitted to carry out her own plan of propagating the white pine her work is more irregular than when assisted by man. Should the seeds leave the cones when there is but little force to the wind they will drop very near each other at no great distance from the parent tree, and the result will be that a hundred small trees will grow on a space not large enough for

more than one large one; but if the seeds leave the cones when the wind is high they will be carried great distances and spread over a wide territory. When man, without too much labor, can assist nature in the more even distribution of the seed it is desirable he should do so, but when he cannot, he may be able to prevent crowding by removing some of the small trees where they cover the ground too thickly, and setting them out in another place where they cannot interfere with each other.

When the seed is to be planted by man, the cones should be gathered just before the first frost in the autumn and placed small end up in the grass away from all enemies. After the first heavy frost, gather up the cones and shell out the seed by turning them small end downward over a vessel and giving them a rap with a stick when the seeds will drop out. As soon as the seed is shelled it should be planted; it is a mistake to dry pine seed several months before planting.

The method of planting must depend on the condition of the soil; if it is a barren plain shallow furrows may be ploughed from east to west five feet apart, turning the furrows to the south to afford a partial shade to the young plants. The seed should be planted on the south side of the open furrow, dropping two seeds near each other, then leaving a space of four or five feet, and covering the seeds with earth enough to keep them moist, say not far from one half an inch in depth. On rocky land, or where the soil is hard, dig out with a sharp spade a small sod where the seeds are to be planted, leaving the sod near the hole on the south side for shade, and planting the seed the same as in furrows. In a favorable season enough seed will germinate to cover the land, but if the season be unfavorable, a portion of the land will have to be reseeded the following year. Where the land is shaded by trees, germination will be more certain; but in such places when the seedling pines are two years old they should be let out into the sunshine by removing the trees that shade them.

In localities where seedling pines that grow naturally are numerous, it is not expensive to cover land with pines by transplanting the young trees; to do this to the best advantage trees should be selected that are not over six inches in height, and in removing them, a small ball of earth should be removed with each tree, care being taken not to expose the roots to the light or the air, and it is always best to do the work on cloudy days, during the month of May. The trees should be set five or six feet apart and as they

grow a sufficient number should be cut out to prevent crowding. When large enough for box-boards or coarse lumber, not more than four or five trees should be left on each rod of land.

On an average soil, thirty-five years is sufficient to produce white pine timber of a profitable size to cut for coarse lumber, and as a rule, on our New England soil, it is more profitable to cut the trees at this age than it is to let them stand long enough to produce trees large enough for clear lumber.   It is a mistake to suppose that trees large enough and good enough for clear lumber can be grown on any soil, it is only on soils best adapted to the growth of the white pine that it is wise to let the trees stand after they are more than twenty inches in diameter.   On ordinary and even on very barren soils, the young trees grow quite rapidly, and unless the soil is very unfavorable, they will make a satisfactory growth until the largest trees are ten or twelve inches in diameter; beyond this size if the land be well covered with trees, a very large portion of them will show signs of decay, and only a few growing in the most favored places will continue to grow rapidly ; thus the decay on the lot will be nearly equal to the growth.

While it requires but from twenty-five to thirty-five years to grow the white pine large enough for box-boards, it requires from sixty to seventy years to grow it large enough for clear lumber. When we consider the fact that there is always a ready sale, at remunerative prices, for coarse lumber, and also the uncertainty of getting first quality of lumber by thirty years of additional growth, it would seem unwise to encourage owners of pine timber forests to let the trees stand after they are large enough for coarse lumber, except on land strong enough to keep up a rapid growth until the trees are three feet or more in diameter.

Four white pine trees set thirty-one years ago now measure, three feet from the ground, as follows ; one 60 inches in circumference, one 65 inches and two 66 inches ; the 65-inch tree grows in a wet soil, the remaining three are in a gravelly loam not rich enough to produce more than 800 pounds of hay to the acre. These trees when transplanted were not over six inches in height, and they have grown with other trees set at the same time so near each other that they now completely shade the land.   Two trees set on a poor gravelly knoll twenty-five years ago, now measure 33 and 39 inches in circumference ; these trees were about twelve inches in height when set ; they have grown on open land.

There have been many opinions advanced in regard to thinning and trimming white pine forests, and these divergent views have to some extent been caused by a difference of opinion as to how long the trees should be permitted to grow. If a pine forest is to be cut when large enough for coarse lumber, it should be treated differently from one that is to stand long enough to make clear lumber; but little need be done with the former except to cut out the dead and dying trees, while the latter should be carefully looked after from the time the trees are eight feet high until the limbs on the trunk are all off to the height of twenty or more feet. As early in the growth of the forest as possible, the trees that are to remain for lumber should be selected and the lower limbs on the trunk cut off as fast as it is considered safe to do so and not injure the vigor of the tree; this work should be done in June. After having chosen the trees that are to make the future forest, all the trees between them should be kept back and destroyed as fast as they appear to crowd the selected trees; but it is well to let the trees between stand quite near to the selected ones until they are twenty feet high if they do not overshadow them. By so doing the trees will grow higher and the trunks will have fewer limbs, thus securing clear lumber; in fact a good white pine timber tree rarely ever grows in an exposed position; it must grow where it is surrounded by other trees or it will not make a long, straight and clear timber log; he who is to trim a timber lot must ever keep this fact in mind, and do his work in such manner as will best assist nature in her efforts to produce trees of the best type for man's use. It is not wise to attempt to grow more than 160 or 170 timber trees to the acre, but by the selection of this number when the forest is young, they may be given ample room to develop, and there will be left room between them to grow a limited number of trees large enough for box-boards.

No. 33. — *Facts gathered by observation and experience relating to the White Pine (Pinus Strobus L.)* By EDMUND HERSEY, Instructor in Agriculture at the Bussey Institution, and Superintendent of the Bussey Farm.

PART II.   VALUE OF THE PINE AS A TIMBER TREE.

When white pine trees are cut down, sawed into lumber, and seasoned at a proper time, *i.e.*, during that portion of the year when the seasoned wood will be left in the best possible condition, the lumber can be used to advantage for a great variety of purposes ; but if the trees are cut in March, sawed into lumber, and dried in the usual manner, all of that portion of the tree which is known as the "sap" will soon be eaten by worms to such an extent as to render the wood of little value for any purpose ; and if the logs are left lying in the air over summer without being sawed, even the heart of many of them will be penetrated by some of the larger worms.

Early in life my attention was called to the keeping qualities of pine timber, by observing the hewed pine beams and rafters which were always exposed to view in the old style barns. While in some barns I could not climb over a beam without being covered with the fine dust, caused by the action of the worms, in others the beams were perfectly sound. The reason for this difference was not discovered until later in life at a time when I was engaged in a business that required large quantities of pine timber, cut at different seasons of the year.

The fact that the season of the year in which the timber was cut made a great difference in its quality, soon became so evident that I gave particular attention to the matter and investigated it thoroughly in order to determine when to cut a tree so that the best results might be secured. After more than forty years of observation and trial, August was found to be the best month, and September, October, November, December, July, and January were found to be the next best, in the order named ; the most undesirable seasons are March, April, and May in the order named, though it needs to be said of Massachusetts that the variations in seasons will sometimes make April a better month than January, or July better than December.

Speaking generally, I have observed that logs cut in March were very badly eaten by worms before October, and if sawed before June the lumber would be badly eaten within eighteen months. As a rule, the finished lumber would pass through the first season without injury, and no worms would appear until the summer of the next year. Consequently, if the lumber was manufactured into wares as soon as seasoned, there was no loss to the manufacturers by worms, and the loss which might accrue subsequently to the consumer would depend on the finish of the manufactured article : if the wood were painted, no loss would occur ; or if it were planed and made into packing boxes, very little loss would occur ; but if put into rough boxes, or made into an unpainted board fence, the loss would be serious.

When logs are cut in the latter part of summer, or in the autumn, and sawed into lumber before the following summer, the boards can be kept for years without injury by worms. A few years ago a house in Hingham, Massachusetts, which had been built seventy-five years, was taken down to be removed and put up again ; the timber, which was of white pine, was found to be perfectly sound except where it had come in contact with the earth. On enquiry, it was proved beyond a doubt that the timber had been cut in early autumn. In the case of another building which was erected at about the same time as the foregoing, it appeared on removal that the white pine timbers were all badly eaten by worms ; in fact the sap wood was completely destroyed, and the heart wood was quite full of large worm-holes. From the best evidence that could be obtained, the timber for this building was cut in February and March. I dwell upon this subject in some detail because it is one of very great importance to all who cut and use timber, and also because it would appear that few persons who have had large experience have given the facts to the public.

The question is often asked, What is the average product of an acre of white pine? And the answers given to it differ so widely that it would almost seem to be impossible to arrive at any correct conclusion. Why this difference of opinion? Probably because of the wide difference between the product of different fields even in any one locality ; and when we consider the whole country, the difference is increased.

Careful measurements and estimates of the product of many

acres of pine timber in Plymouth County, Massachusetts, have led me to the conclusion that where there is no other timber mixed with the pine, on a warm, loamy soil, in a growth of from thirty to thirty-five years, one hundred thousand feet of box boards may be obtained; but on an average soil the usual thirty-years' growth has been found to be about fifty thousand feet, when but little other wood is mixed with it. The expense of cutting, drawing, sawing, and drying, is from $5.00 to $6.00 per thousand feet; which at the present price of box-boards would leave the owner of the land about $2.50 per thousand on the stump, or $125.00 per acre. This sum would pay a good interest on the investment, if the land had cost not more than $15.00 per acre when the pines first started to grow.

During the civil war, at a time when I was paying $13.00 per thousand for box-boards, one acre of white pine trees in Scituate, Massachusetts, was put out to be cut and sawed into box-boards on shares; the owner to have half the money the boards sold for; he received $500.00 for his share. As the contractor kept his own account and paid the owner whatever he pleased, it is fair to presume he did not pay more than half the amount he had obtained from the acre. These trees had been growing not over forty years. To secure a growth like this, it is not only necessary to have a good soil, but also to have the ground well covered with trees. When nature is left to her own way, there are, almost always, open spaces of one or more rods where no seedlings start. With very little labor, when the seedlings are small, these spaces might be filled with trees from portions of the field where there is a surplus, and in this way it would be easy to secure one-hundred-thousand feet of box-boards in thirty years from each acre of land of good soil, provided, of course, that the land can be kept free from fires. A careful measurement of land, and counting of trees in a large number of forests in eastern Massachusetts, leads me to the conclusion that three trees will grow on each rod of land, in thirty or thirty-five years, to a size of sixteen inches in diameter one foot from the ground, and high enough for the three to make eight hundred feet of box-boards; at this rate, an acre would produce one hundred and twenty-eight thousand feet.

At thirty-five years of age many of the trees in the pine forests of eastern Massachusetts commonly show signs of decay, except

on very strong soil. As a rule, in this locality, white pines growing on a light, sandy soil, should be cut for box-boards when they have stood from thirty to thirty-five years, if the greatest profit is to be secured; after that time, the decay of the smaller trees, and the amount of interest money which would be lost, would not be made up by the growth of the larger ones. In a rich soil well adapted to the growth of the pine, it would, no doubt, sometimes pay to let the trees stand for fifty or seventy-five years; but such cases would be rare in eastern Massachusetts, and would apply only to small groups of trees.

To grow on our worn-out pastures, large pine trees for clear lumber, equal to the primeval growth, as advocated by some writers, would be as difficult as to grow large potatoes on a sandbank. Nature has a way of her own of preparing the soil for the growth of large trees as well as small plants; her first efforts are to cover the barren soil with very minute plants, and she changes the species as the decayed vegetation prepares the soil for larger plants. The first growth of trees on a soil where the growth of vegetation has been limited, is of medium size for its species, and a very large growth only comes when the soil is fully prepared to carry out such growth. It is well to remember this truth when we start a plantation of pines for the growth of logs three or four feet in diameter, and trees one hundred feet in height. A little investigation will lead a close observer to the conclusion, that on most of the soils of Massachusetts where the land has not been covered with forests for many years, pine timber of medium size can be grown to a greater profit than large trees for clear lumber.

We should not overlook the fact that in Massachusetts the larger portion of the rich lands adapted to the growth of the white pine, are already utilized for the cultivation of farm crops which find a ready market in from one to three years after planting. Such land would be too valuable to set with trees which would require from seventy-five to one hundred years to mature. The lands which are left that can be bought at a low price, and which seem to promise the best for the profitable production of pine lumber, are the light lands of the plains, which have been cropped so many years that they have been abandoned, and left to nature to perform the work of restoring them to their former richness. Man is impatient, and unwilling to await the slow process of nature;

but by his intelligent labor he could assist her to cover these barren lands with white pine trees, which in thirty or thirty-five years would grow large enough for cheap lumber; he could then cut them, and leave the land in as good condition for nature to grow various crops, as it would have been as if no trees had been grown on it. If fires could be prevented, and if man would lay aside profit, and wait two or three hundred years for nature to pursue her own way, she would grow crop after crop of trees each perhaps larger than the other, and let them fall to the earth and decay, until a soil had been formed adapted to the growth of pine trees large enough for clear lumber; but to expect a pine tree to grow four feet in diameter at the ground, and rise to one hundred feet in height, with a smooth, straight trunk, in seventy-five or a hundred years, on a comparatively barren soil, is asking of nature too much. Let us be reasonable, and be satisfied with the smaller growth, which can be secured in half the time.

The remarks in this paper relative to the time of cutting trees and the injury by worms, refer to the second growth pine trees cut and sawed into lumber without being soaked in water. Pine timber cut and floated down the rivers, and kept in the water all summer before being sawed, would probably lose those attractive constituents which induce the miller to deposit the eggs that produce the worm or borer, and thus if cut at any season would be likely to escape injury.

No. 34. — *Facts gathered by observation and experience relating to the White Pine (Pinus Strobus L).* By EDMUND HERSEY, Instructor in Agriculture at the Bussey Institution, and Superintendent of the Bussey Farm.

PART III.   AN ANSWER TO CRITICISMS OF PART II.

In an article published in the journal entitled "Forest and Garden" for May 20, 1896, Mr. B. E. Fernow of the United States Department of Agriculture, has seen fit to doubt the accuracy of certain facts as stated by me in Part II. of this series of papers. Since I have abundant evidence wherewith to prove that Mr. Fernow's criticisms are incorrect and unfounded, I feel called upon to issue this Supplementary Part III. for the benefit of those who are seeking facts relating to the White Pine as grown in Plymouth County, Massachusetts, in order to prevent them from being led into error by false theories.

Mr. Fernow says, —

"One of the elements that need to be known in order to discuss the profitableness of forestry is the amount of useful wood which can be produced per acre. On this point the most erroneous and extravagant notions exist, and many calculations are made on paper which can never be realized. The rate of growth of a tree at a given age is supposed to continue indefinitely, and this rate is applied to an acre of trees . . . and thus we can compute astonishing yields for the future."

To this statement I fully agree; and I would add, as a practical manufacturer of lumber, that I am disgusted with those who, without any real knowledge, such as is learned in the saw-mill, measure a few trees, or employ agents to do so, and rush into print with an array of figures which have about as much effect in changing what are known to be positive facts as a feather would have in removing a mountain of iron, by being blown against it by a gentle summer breeze.

When Mr. Fernow pronounces my paper to be the "latest contribution to rosy prospects," he places himself in the unfortunate position of trying to discredit statements of established facts.

For many years I was engaged in buying large quantities of pine trees ; and as the custom was at that time, I bought them on the stump, in many cases by the measured acre.   It was my practice to hire the logs drawn to the mill by the cord of 128 cubic feet ; each load was measured by a sworn surveyor, and the boards, after being sawed, were also measured by a sworn surveyor ; thus I was able to get at positive results.   It may be of some interest to Mr. Fernow to know that 128 cubic feet of logs, measuring from seven to fifteen inches in diameter (a fair proportion of each as they average), will make one thousand feet of five-eighth inch box-boards (surface measurement), and that I have frequently got more than sixty thousand feet from an acre of land.

As I am accused of making " rosy " statements, perhaps an effort may be made to discredit this one, unless it is sustained by the testimony of practical men whose words it would be useless to try to discredit in the localities where they are known.   The following citations are from letters addressed to me by practical men in Plymouth County in response to my inquiries.

Mr. Charles H. Dwelley of West Hanover, Mass., testifies as follows, —

"I have cut two hundred cords of pine timber from two acres of land ; the trees had been growing fifty years.   I do not think that the gain had been anything for ten years previous to cutting : the loss by dead trees was equal to the growth made by the living.   I cut from the same lot, before the two hundred cords above stated were cut, thirty cords of decayed trees, twenty cords of which were large enough for box-logs.   I carted to the mill owned by E. Y. Perry, fifty-three cords of logs surveyed on the wagon, and the return from the mill was fifty-three thousand and fifty-eight feet of five-eighth inch box-boards."

Mr. Frank Stockbridge of Hanover, Mass., says, —

" Two years ago, I cut off two acres of average pines of thirty years' growth that produced one hundred thousand feet of five-eighth inch boards."

He also says, —

" A cord of logs will produce on an average one thousand feet of box-boards, and sometimes twelve hundred feet, depending on size and quality of logs."

Mr. Samuel Dyer of Whitman, Mass., states, —

"I had one cord of good, straight, pine logs, from six to fifteen inches in diameter, brought to me by C. D. Dyer, and sawed by Warren Wilkins, that made eleven hundred and forty-five feet of five-eighth inch box-boards, and I have cut from one acre of land one hundred and seventy-eight thousand feet of five-eighth inch box-boards."

The age of these trees is not known. Mr. Dyer says he is ready to furnish proof of the truth of his statement if it is doubted.

Many similar statements could be furnished, if it were necessary; but I consider it a waste of time to add any more. The writers above cited are careful and intelligent men of unquestioned integrity; and it is to be noted that their knowledge has been arrived at by a method of procedure which gave them positive information both as to the products of a given quantity of land, and as to the quantity of boards obtained from a given number of cubic feet of logs. Inasmuch as I have myself set out many pines and other trees, and watched their growth and measured them while growing; have cut them down, counted the rings and compared the number of rings with the known age of the trees, I ought to be able to know enough about the age of a pine forest to tell whether it has been growing thirty or fifty years, — provided, of course, that I possess ordinary intelligence.

As I have stated before, my papers have been written for Massachusetts, and particularly for Plymouth County, where pine trees grow more rapidly than in some other counties. I once owned a saw-mill in Franklin County, where I cut and sawed many cords of pine timber; but not enough to justify me in rushing into print with the results, except to say, that judging from the length of the clear lumber between the limbs, I think it would take fifty years to get there as large a growth as could be obtained in Plymouth County in thirty years.

Mr. Fernow's mistake is in judging Plymouth County by more unfavorable portions of the country and by drawing conclusions from measurements of a few standing trees. To show how unreliable this method is, I will give the measurements of a few pine trees that meet my view as I look up from my writing table; these trees were set out thirty-five years ago last spring (1896), being, when set, not over six inches in height.

The measurements here given were made early in the spring of 1896 : —

Tree No. 1 . . . . 72 inches in circumference.
" " 2 . . . . 72 " "
" " 3 . . . . 69½ " "
" " 4 . . . . 62 " "
" " 5 . . . . 58 " "
" " 6 . . . . 57½ " "
" " 7 . . . . 57 " "
" " 8 . . . . 48 " "

If I had desired to write a rose-colored paper, I might have drawn conclusions from these trees and from many other groups which have made an equally good growth; but what I write for the public, is that which I have found in practice to be true, or what by observation I have good reasons to believe to be true.

Many of those who put before the public what they believe to be an average or possible product of lumber on a given area of land, found their belief on measurements of standing trees, and figure out on paper what a given number of cubic feet of logs will produce of sawed lumber without recognizing the fact that while in one locality logs may be so valuable on the stump, that the greatest economy, and the most intelligent labor, will be employed to manufacture them into lumber; in other localities trees may be so cheap that speed in working them will be sought for regardless of economy, and a waste of one quarter, if not one half, of the material may be the result. Thus a writer on the products of our forest lands needs to be not only a practical lumberman, but one who understands the difference between a sawmill constructed for economy, and one constructed for speed regardless of economy, otherwise he will too often find his opinions at variance with those of men who have actual practical knowledge of what they are writing about.

September 10, 1896.

No. 35.—*Observations on Some of the Chemical Substances
in the Trunks of Trees.* By F. H. STORER, Professor of
Agricultural Chemistry.

It has often been assumed that starch stored in the tree before
the advent of winter is the chief or even the sole source of the
sugars of one kind or another which in cold countries appear in
the spring in the sap of many forest trees. Other observers have
suggested that a part, at least, of the reserve food in trees, exists
there in the form of hemicelluloses which may be changed to sugar
in due course. This view finds support in the fact that some part
of the hemicelluloses in wood are easily made soluble by the
action of acids and alkalies; that much of the reserve food stored
in cabbages and turnips and some other roots is palpably in the
state of hemicelluloses, and that in the so to say historic in-
stance of the course of germination of date-stones (and various
other hard seeds) it has been noticed, by several distinguished
observers, that the hemicelluloses of the seed serve to nourish
the young shoot.

The results of analyses made in this laboratory go to show
that there is still much to be learned in respect to the reserve
matters in the wood of trees, and they suggest the questions
whether undue stress may not have been laid sometimes on the
storing up of starch, and too little attention have been paid to
the differences which really exist between those hexosans (such as
mannans and galactans), which are known to be capable of sup-
plying food to germinating plants and the comparatively speaking
inert pentosans (xylan, for example), which abound in the wood
of many trees.

The analyses recorded below indicate that the quantity of re-
serve starch stored in the trunks of trees is ordinarily not so
large as has sometimes been stated. It is noticeable, withal,
that the proportion of starch, in the woods thus far examined,
varies less widely at different seasons than might have been sup-
posed from statements which still pass current, in spite of the
observations of several botanical investigators who have seen with
the microscope that starch exists in the wood of trees not only in
autumn and winter, but in the spring and summer also, and have
suggested that the variations in the amount of starch contained

in wood at different seasons may, perhaps, depend upon other motives than the necessity of feeding buds and leaves in the spring. The analyses go to show, furthermore, that the pentosans in the wood of trees can hardly be regarded as of the nature of reserve food, though it must be admitted that we are still profoundly ignorant as to the chemical behaviour of these substances within the tree.

Percentage of Pentosans found in the Wood of the Gray Birch
(Betula populifolia of Aiton).

Segments of wood were sawed out from the stems of the trees at a height about twenty feet from the surface of the ground, where the stems were a little more than three inches in diameter, and where eighteen annual rings could be counted. After the bark, both outer and inner, had been peeled and shaved off, the blocks of wood were divided into an outer and an inner portion by drawing a circle seven-eigths of an inch in radius from the centre of the stem and chipping off the wood outside this circle with a chisel. The samples of " outer " and " inner " wood thus obtained, were chipped into small pegs which were dried, ground in a mill and powdered. The outer bark was thrown away, but the inner bark was examined as stated in the text.

To estimate pentosans,* weighed portions of wood were distilled with hydrochloric acid of sp. gr. 1.06, the distillate was mixed and stirred with phenylhydrazin acetate, the precipitate was collected on an asbestos filter, then dissolved in alcohol, as suggested by Krug, and dried thoroughly at about 60° C. The weight of the precipitate multiplied by 0.516, gives the theoretical weight of the furfurol, and to this weight has been added the conventional correction 0.0101, to compensate for matter dissolved from the precipitate during the process of washing, and for incomplete subsidence of the precipitate also.

Percentage of Furfurol obtained from the Wood of Gray Birch
Trees felled at Different Seasons.

From the tree felled in	There was obtained per cent of furfurol (wood dry at 100° C.) from the		
	Inner Wood.	Outer Wood.	Bark.
May	21.32	19.62	16.75
July . . . . (I.) 16.55	(II.) 16.62	18.84	11.45
October	16.21	16.29	12.32

* See Wiley's Principles and Practice of Agricultural Analysis. Easton, 1897. **3.** 179, 183, 587.

On multiplying these figures by the conventional factor 1.84,* the results may be stated in terms of pentosans, as follows: —

The tree felled in	Contained pentosans, per cent, in the		
	Inner Wood.	Outer Wood.	Bark.
May 39.23		36.10	30.82
July . . . . (I.) 30.45		34.67	21.07
" . . . . (II.) 30.59			
October 29.83		29.97	22.67

See, further, page 395, for the quantities of pentosans detected in other kinds of woods.

It will be noticed that the proportion of pentosans in birch wood is somewhat larger in May than in October, presumably because other matters were stored in the tree in October and exhausted from the tree in May, though it is to be said that the method of estimating furfurol by means of phenylhydrazin acetate is hardly sufficiently accurate, as an analytical process, to permit of too much emphasis being laid on the observations here recorded. It is to be remembered also that a small proportion of the furfurol obtained may, perhaps, have come from albuminoids or from hexoses in the wood.†

As a matter of course fatty and nitrogenous matters in the tree may serve as well as starch for feeding new buds and leaves, and it is true also that the twigs and young branches of a tree will naturally be richer in starch than the older wood of the trunk or stem. It is not impossible that these matters acting in conjunction with the comparatively small quantities of starch found in the older wood and bark, may be sufficient to provide the tree each year with its new suit of leaves, even as in the familiar instance of the taking of carbon from the air by green leaves mere traces of matter are seen to be competent to produce effects of enormous magnitude. Still it would seem to be more probable that, beside starch, oil, and albuminoids, there are contained in wood and bark other chemical substances, presumably hexosans, which may take part in the act of developing new foliage.

From the analogy of the hard seeds of the date and other palm-trees, which contain a much smaller proportion of pentosans than wood contains, but which are known to be rich in hexosans and to be fully competent to supply food to the young plant at the

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* Wiley's Agricultural Analysis, 3. 587.

† De Chalmot, American Chemical Journal. 1893, **15**. 23, 277. Tollens, Kurzes Handbuch der Kohlenhydrate, Breslau. 1895, **2**. 52, 73, 163.

moment of germination, it might be suspected, not unnaturally, that certain hexosans (mannans or galactans) in the hemicelluloses of wood may undergo change in the spring and be converted into sugar, while the pentosans perhaps may not be subject to this particular kind of change. I hope to be able to study this question. Meanwhile, it is to be noted that Lindsay and Tollens * found mannose and galactose in "sulphite liquor," a waste product from works in which paper-pulp is prepared from spruce wood by the sulphite process, and that it has long been familiarly known that the sap of birch trees in the spring contains an abundance of a fermentable hexose. It is reported, indeed, as a matter of history, in the Encyclopædias of Agriculture, that birch wine and birch vinegar were prepared habitually at one time in certain wild districts, and that at the siege of Hamburg in 1814, many birch trees in that vicinity were destroyed "by barbarian soldiers in the Russian service," in their efforts to obtain from the trees the fermentable juice.

Quantities of Starch (and Sugar) Found in Certain Woods.

The results here given were obtained by means of the method described on page 198 (§180), of Vol. III of Wiley's Book on Agricultural Analysis, which consists in leaching the wood with ether, to remove fats, and then acting upon it, at a temperature of about 65° C., with diastase, as contained in a measured volume of fresh extract of malt, and estimating in the usual way, by means of copper, the sugar which has been formed from starch in the wood. A correction is made, of course, for the small amount of sugar in the malt extract used.

Kind of Wood.	Per cent of Starch (and Sugar) in wood dry at 100° C. As obtained by the malt process:		
	Inner Wood.	Outer Wood.	Bark.
Gray Birch felled in May	4.93	5.42	7.67
" " " July	3.83	3.87	7.52
" " " October . . .	3.75	3.51	4.24
Sugar Maple " "	1.94	2.43	5.97
Alder felled in January	. .	3.04	. .

Ivory Nut † . . . 6.57
Date Stones . (I.) 5.44 ⎫
"   "   . (II.) 4.46 ⎬ Separate samples and different analysts.
Apricot Stones . . 1.46 ⎭

* Versuchs-Stationen. **39.** 423, 424.
† The so-called Vegetable Ivory, the seed of the South American plant, Phytelephas macrocarpa. For an abundant supply of turnings from the ivory

It is to be said that in these trials no attempt was made to separate from the starch any sugar which may have been contained ready formed in the woods at the moment of their examination. It is to be presumed that in several instances, small quantities of sugar as well as of starch were actually contained in the substances examined. In the case of the ivory nut, for example, Reiss * found half of one per cent of sugar (" dextrose ") soluble in water in a sample examined by him, and Grüss† has noticed that the mannan in date-stones dissolves — as it does in the act of germination — when exposed for a very long time to the action of diastase.

It will be noticed that, in conformity with the experience of other observers, the analyses above given exhibit a marked tendency on the part of starch to accumulate in the bark of trees rather than in the wood proper. This fact accords with common experience in respect to the habits of many animals which feed upon bark in preference to wood. Mice and rabbits, for example, working beneath the snow in severe winter weather, often destroy young fruit trees by eating away the bark from off the wood. The beaver is known to subsist principally upon the bark of small limbs of the yellow birch and of certain poplars and willows, beside that of alders, maples, and other deciduous trees. According to Morgan,‡ it is only in late winter that beavers eat clear wood § and such roots as they can reach from their burrows or find in the banks of streams. The American porcupine also feeds upon the living bark of trees stripped from their branches.

Indeed, it was customary formerly in many countries, in times of dearth, notably in Sweden and Norway, to prepare bread which contained a considerable admixture of pulverized bark. So recently as 1854, von Berg collected samples of " bark-bread " in Sweden which

nut, I am indebted to the civility of Messrs. Newell Bros. of Springfield, Mass. As received, the snow white turnings were contaminated with a small proportion of fragments of the dark-colored outward coating or skin of the nut, but pains were taken to pick out and remove these specks before subjecting the pure material to chemical examination.

* Landwirthschaftliche Jahrbücher. **18.** 745.

† Tollens's Kohlenhydrate. **2.** 367.

‡ L. H. Morgan, The American Beaver. Philadelphia. 1868, pp. 166, 183.

§ Many years ago I was told by Jeffries Wyman that, on dissecting a beaver, he had found in the intestinal tract of the animal segments of birch twigs of considerable size, the outer bark of which was still perfectly sound, while the wood itself had been thoroughly reduced by the digestive juices to a soft, smooth pap or chyme, which could readily be scraped or squeezed out from the bark cylinder which held it in place. — F. H. S.

were analyzed by Dietrich * in Stoeckhardt's laboratory.   In 1853 the naturalist Seeman † wrote as follows : —

" The practice of mixing alder bark (Alnus incana) with dough is not now in use at Petropaulowski, but is still prevalent among the natives in the interior."

As regards the trustworthiness of the figures for starch (and sugar) above given, it is manifest that by means of malt, as appled in the manner stated, it is practicable to obtain a fairly accurate estimation of the amount of starch naturally contained in a wood. That is to say, the starch may be determined with adequate accuracy, after any sugar which may be contained in the wood has been washed out, and the amount of it estimated. Due attention should be paid to the consideration of this point, because of the fact that the much higher figures as to the quantity of starch in woods which have occasionally been published, undoubtedly depend in some cases upon the employment of improper methods of analysis. As will appear directly, it is quite impracticable to estimate the starch in wood by means of methods which depend upon the conversion of starch to sugar by the action of hot dilute acids. Thus the method of estimating starch devised by Sachsse, which as Winton ‡ has shown, is well fitted for use upon starch-bearing grains and tubers, is not in the least applicable for determining the starch in woods, because there is produced by the action of the acid upon the wood a quantity of pentoses, which reduce the copper salt as readily as does the dextrose which is formed simultaneously with them by the action of the acid upon starch.

Results obtained by Subjecting Wood to the Action of Hot Dilute Hydrochloric Acid of about 2.5%, as in Sachsse's § Process for Estimating Starch.

Three grm. portions of the powdered woods were treated with a mixture of 200 cc. of water and 20 cc. of hydrochloric acid of sp. gr. 1.125, and heated during three hours in a boiling waterbath, and the sugar thus formed was determined by means of copper, according to Allihn.‖   It is manifest from the results

* Der Chemische Ackersmann.   1855, 1. 105.

† Voyage of the Herald.   2. 6.

‡ Report of the Connecticut Agricultural Experiment Station.   1887, p. 128.

§ Chem. Centralblatt.   1877, 8. 732.   See also Wiley's Agricultural Analysis.   3. 203, 205.

‖ See Wiley's Agricultural Analysis.   3. 155.

obtained with malt, as stated on page 389, that most of the sugar formed by the action of acids in these experiments, must have come, not from starch in the wood, but from hemicelluloses of one kind or another, presumably from pentosans for the most part. In the absence of certainty as to this point, an attempt has been made to get a rough conception of the quantity of pentosans by proceeding as if the copper found represented dextrose; *i.e.* dextrose was computed from the copper, by means of Allihn's table, and this so-called dextrose, which was presumably xylose for the most part, was multiplied with the factor 0.88 * to convert it into terms of xylan.†

In the cases of the ivory nut and date stones, which are rich in mannan and poor in pentosans, the sugar obtained by the action of acids has been calculated as a hexosan by multiplying with the factor 0.9. Speaking in a general way, the reducing action of xylose and dextrose upon copper salts is very nearly the same,‡ but the details of the action of xylose appear never to have been worked out.

Pentosans obtained from Woods by means of Sachsse's Acid, i. e., *Acid containing about $2\frac{1}{2}$ per cent of* H Cl.

Kind of Wood.	Per cent of pentosans (wood dry at 100° C.).		
	Inner Wood.	Outer Wood.	Bark.
Gray Birch felled in May 22.00		25.25	22.91
·' " " " July 22.74		22.16	21.49
" " " " October 21.87		(I.) 24.55	28.93
" " " " "		(II.) 23.85	
Alder " " January 25.11		25.63	26.15
Sugar Maple " " October 19.59		20.47	..
White Pine (unknown) 12.16		..	..
Apricot Stones § 23.50			
Peach " § 20.83			
Ivory Nut (paramannan) 32.30			
Date Stones · " . . . . (I.) 25.05			
" " " . . . . (II.) 27.52			

Two different samples. (for Date Stones)

When the woods were subjected to a less severe treatment with acid than obtains in Sachsse's process, *i. e.*, when they were boiled

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* $0.88 = \dfrac{132}{150} = \dfrac{\text{Molecular weight of xylan } (C_5H_8O_4)}{\text{Molecular weight of xylose } (C_5H_{10}O_5)}.$

† Compare E. Schulze, Versuchs-Stationen. **36.** 457, 460 *note;* **41.** 228; and Winterstein, Ibid. **41.** 378.

‡ Stone, American Chemical Journal. **13.** 82.

§ The hard outer shell which encloses the kernel.

during one hour with hydrochloric acid of 1%, according to Stone's * suggestion, and the sugar thus formed was estimated with copper and calculated from Allihn's table, as before, there were obtained the results which are set forth in the following table : —

Pentosans obtained with Acid of One per cent.

Kind of Wood.					Per cent of pentosans (wood dry at 100° C.).		
					Inner Wood.	Outer Wood.	Bark.
Gray Birch felled in May					12.49	11.41	(I.) 12.42
"	"	"	"	"		..	(II.) 12.21
"	"	"	" July		9.88	11.20	12.32
"	"	"	" October	(I.) 11.60	12.05 }	15.06
"	"	"	" "	(II.) 12.01	12.01 }	
Apricot Stones							12.56
Peach "							9.04
Ivory Nut							21.78 (Paramannan).
Date Stones							19.39 "

On comparing these results, as obtained with woods, with those stated previously in the table on page 392, which were obtained by boiling the woods during three hours in hydrochloric acid of about 2.5%, it will be seen that the quantities of xylan hydrolized in the two cases are in some measure proportionate to the strength of the acid employed and to the length of time during which the acid is made to act. Indeed, on subtracting from the figures obtained by the use of 1% acid, the quantities of " starch," as determined by means of diastase, it will be perceived that the action of the 1% acid on the woods was distinctly feeble. These results are in full accord with those of Winterstein,† who found that much more of the xylan in beech wood was hydrolized by sulphuric acid of 5% than by that of 1.25%.

In respect to the hexosans in date stones and the ivory nut, it will be noticed that the action of both the acids was more pronounced than it was in the case of the woods. But here again, contrary to E. Schulze's experience with paragalactan,‡ which he found to be about as readily soluble in hydrochloric acid of 1% as in a somewhat stronger acid, the weaker acid did less service than the stronger. It is not impossible, however, that by the persistent application of fresh portions of moderately strong acid, almost the

* U. S. Department of Agriculture, Office of Experiment Stations, Bulletin No. 34, p. 13.

† Zeitschrift für physiologische Chemie. **17.** 384.

‡ Versuchs-Stationen. **36.** 447; Landwirthschaftliche Jahrbücher. **21.** 91, 94, 101.

whole of the mannan in the date stones and the ivory nut might eventually be hydrolized.

On contrasting the percentage of furfurol obtained from the original date stones and ivory nut with the quantities of furfurol obtained from the residues left after dilute acids had been made to act on these materials, it will be seen that the residues retained a very large proportion of the original pentosans. In other words, it would seem as if the hydrolizing acids had acted first or at the least more readily upon the hexosan (paramannan) in the date stones and the ivory nut, than they did upon the xylan in these materials.

As an example of the influence of time upon the action of the dilute acid, it may be mentioned that while one sample of the inner wood of the birch tree felled in May, on being boiled for one hour with hydrochloric acid of 1%, gave 12.49% of pentosans, a second sample, boiled in a similar way for an hour and a quarter, gave 13.70%. For that matter, there are numberless experiments on record which go to show how extremely liable to variation are the results of the hydrolysis of hemicelluloses by means of acids. As every agricultural chemist knows, the diverse results often obtained by the so-called Weende method of estimating cellulose illustrate the point sufficiently.* On the other hand, too long continued action of the acid may sometimes diminish the yield of sugar. Hawey † and Winton ‡ have both shown by test experiments, that some dextrose may be destroyed by very long continued boiling of it in presence of the acid by which it has been formed. As regards pentoses also, C. Schulze and Tollens § have found that the yield of sugar may be very much lessened if, in the process of hydrolizing a pentosan, the boiling should be too long continued or if too strong an acid be used. It is to be presumed, however, that in the foregoing experiments on the hydrolysis of woods, the action of the acid was seldom or never

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* Compare, for example, some of the instances cited by Reiss, Landwirthschaftliche Jahrbücher. **18.** 743, 744. See also, Krauch, Versuchs-Stationen. **24.** 296. **25.** 225, 226, and E. Schulze and Steiger, Versuchs-Stationen. **36.** 458.

† Cited in Hoffmann's Jahresbericht. 1887, **30.** 337.

‡ Report of Connecticut Agricultural Experiment Station. 1887, p. 180. See also, E. Schulze, Zeitschrift für physiologische Chemie. **19.** 51.

§ Liebig's Annalen der Chemie. **271.** 59.

complete, probably because the efficiency of the acid was lessened by the presence of the products of the hydrolysis and because some part of the wood was shielded by overlying portions from the action of the acid. In like manner, C. Schulze and Tollens,[*] in their work on brewers' grains, were unable to hydrolize completely, by means of dilute acid in a single operation, the pentosans in that material.

Generally speaking, the quantity of pentosans obtained by the method of hydrolizing the woods with dilute acids, as stated in the foregoing tables, was less than that found by distilling the woods for furfurol; and it is noteworthy, that very considerable quantities of furfurol were obtained always on subjecting to distillation with 12% acid the insoluble residues which were left after the action of the dilute acids in the experiments on hydrolysis. Attention has been called by numerous observers, to the extreme difficulty of separating some hemicelluloses, notably xylan and paramannan, from cellulose proper; and it has been suggested repeatedly,[†] that it may well be true, that the cellulose and xylan in woods should be regarded as a chemical compound rather than as a simple mixture.

Beside the tests upon the wood of the Gray Birch, as described on page 387, furfurol was determined by the same gravimetric method in other kinds of woods, as stated in the following table.

Furfurol from Other Woods than Birch.

Kind of Wood.	Per cent of Furfurol obtained from materials dry at 100° C.		
	Inner Wood.	Outer Wood.	Bark.
Sugar Maple felled in October	20.71	18.18	10.48
Alder felled in January	10.93	I. 11.89 II. 10.76	11.32
Ivory Nut	(I.) 3.68		
" "	(II.) 3.40		
Date Stones	(I.) 5.24		
" "	(II.) 3.85		
Apricot Stones	18.38		
Peach Stones	15.02		
Cane Sugar (commercial, granulated)	1.63		
Tannic Acid, C. P.	None.		

* Versuchs-Stationen. **40.** 374.

† See, for example, Krauch, Versuchs-Stationen. **25.** 240; Tollens, Ibid. **40.** 377; and in his Handbuch der Kohlenhydrate. **2.** 251. *Cf.* E. Schulze, Landwirthschaftliche Jahrbücher. 1894, **23.** 2; Winterstein, Zeitschrift für physiologische Chemie. **17.** 390; and Cross and Bevan, "Cellulose," p. 156.

Per cent of Pentosans Corresponding to the Furfurol of the Foregoing Table, i. e. *Furfurol* × 1.84.

Kind of Wood.	Per cent of Pentosans in materials dry at 100° C.		
	Inner Wood.	Outer Wood.	Bark.
Birch Wood (see p. 388).			
Sugar Maple felled in October . . 38.10		33.46	19.29
Alder felled in January 20.11		I. 21.88 II. 19.79 }	20.83
Ivory Nut . . . . (I.) 6.77			
" " . . . . (II.) 6.25			
Date Stones . . . . (I.) 9.64 } Different samples and			
" " . . . . (II.) 7.08 } different analysts.			
Apricot Stones 33.81			
Peach Stones 27.64			
Cane Sugar 3.00			
Tannic Acid, C. P. 0.00			

The comparatively small proportion of pentosans in the date stone and ivory nut, taken in connection with the fact that these particular seeds are known to contain much mannan (*i. e.* a hexosan) points to the conclusion that in the germination of these seeds it is the hexosan rather than a pentosan which serves to nourish the young sprout.[*]

So too, as bearing upon the question whether pentoses (xylose) are to be regarded as a food, assimilable by animals, or — stated in somewhat different terms — whether xylan is to be spoken of as a foddering material in the same sense as the insoluble hexosans, it is of interest to recall the facts that those chemists who have tried occasionally, for experimental purposes, to feed cattle or sheep with sawdust have found that some little trouble and trickery are necessary in order that the animals may be induced to eat the powdered wood, while it is known that the horn-like hexosans of the ivory nut, and of date stones and other palm seeds — which are as hard or harder than most woods — are, when powdered, readily eaten and utilized by animals. Indeed, Tsuji [†] has called attention to the use as human food in Japanese households of the root of Conophallus konnjaku, the dry matter of which is said to contain at least fifty per cent of mannan and probably much more.

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[*] See, for example, Reiss, Landw. Jahrbücher. 1889, **18**. 748, *et seq.*, 756, 757, 764; Hoffmeister, Ibid. **17**. 244; E. Schulze and Steiger, Ver-suchs-Stationen. **36**. 456.

[†] Versuchs-Stationen. **45**. 436.

As I have set forth in a previous paper,[*] date stones are an approved food for camels, and the coarse powder of the ivory nut has been used, even in this country, for feeding horned cattle. Both cattle and sheep eat the meal with great relish and fatten upon it.[†]   In respect to their chemical composition, both these substances are akin to palm nut cake,[‡] which has been used extensively in Europe for feeding cows and which is held to be a peculiarly excellent fodder.   The point of interest is that the hard date stones and ivory nut (and the palm nut cake) contain a great store of hexosans while sawdust consists largely of the pentosan xylan.

The question whether the actual sugars (pentoses) derived from pentosans are assimilable by animals has been discussed by several chemists,[§] but in the light of the evidence thus far accumulated it would seem that at the best the pentose sugars must be regarded as very much less valuable foods than the hexose sugars.

As for the pentosans themselves, in the condition in which they occur in vegetable matters, Stone [‖] has expressed the conviction—based on the results of many experiments made by him — that the pentosans are to a marked degree less digestible than the better known hexosans and that they are of less value than the latter as cattle food.   This conclusion was foreshadowed by a notable experiment made — at the suggestion of Professor Engelhardt of St. Petersburg—by a student named Gudkow [**] who fed a pig for a month with nothing but wheat-bran and observed that the excrements of the animal contained a much higher percentage of xylan than was contained in the original bran.[††]

[*] See Bulletin of the Bussey Institution. 1876, **1**. 373.

[†] Report of the Connecticut Agricultural Experiment Station. 1880, p. 86. Liebscher and Schuster, Landwirthschaftliche Jahrbücher. 1890, **19**. 143, 155.

[‡] Press cake from the seeds of the oil palm, *Elaeis Guineensis*.

[§] Notably by Goetze and Pfeiffer, Versuchs-Stationen. **47**. 80, 93; *Cf.* Ibid. **49**. 108, and Weiske, Zeitschrift für physiologische Chemie. **20**. 488.

[‖] American Chemical Journal. **14**. 13; further, Agricultural Science. **7**. 19. See also, Weiske, Zeitschrift für physiologische Chemie. **20**. 488, and F. Lehmann, as cited in Landwirthschaftliche Jahrbücher. **21**. 98.

[**] Zeitschrift für Chemie. 1870 [N. F.], **6**. 360, 363, 365.

[††] It is worthy of remark that the work of Gudkow (and Engelhardt) did much more than exhibit the difficult digestibility of the pentosans in bran. Pains were taken to prove that bran contains a peculiar substance from which furfurol is obtained on distilling it with acids, and a new kind of sugar (now known to be a pentose) was prepared from the substance which yields fur-

As regards sawdust, elaborate experiments upon sheep made by Professor F. Lehmann * at Goettingen, have shown that so very small a proportion of this material is digested by these animals that it may safely be said, practically speaking, that sawdust is indigestible and altogether worthless as a food for sheep.

NOTE. — To the items of evidence relating to the fodder value of palm seeds which were given in volume I of the Bussey Bulletin, may here be added the following additional citations which have happened to fall under my notice : — According to Rich,† Strabo (lib. xvi, p. 511), when speaking of the uses to which the Babylonians applied the date in his time, says among other things that "the stones supplied the smiths with charcoal ; or, being macerated, afforded food for cattle."

Tristram,‡ writing of Ghardaia, says, "Among other articles sold here were heaps of date stones, which we were told were food for camels. Knowing the power of a camel's tooth, we yet wondered at this, these stones being too hard a nut even for a camel to crack, until we observed in front of the doors many rounded holes, in fact mortars, worked out of the roadway, which is the hardest of rock. At these the boys were busily employed towards evening in pounding the date stones for their camels." Again, on page 243, at Waregla, "The camels munched date stones while the horses were fed on dates and date stalks."

So too in respect to the doum palm, there is abundant evidence that the stones of this tree are used for feeding animals. Loudon says : — "In Upper Egypt, they even grind the hard stones in their hand mills for their camels." Warburton § says, "In Upper Egypt, the country of the doum palm, even the kernels of its fruit are bruised for the food of camels." And Sir Samuel Baker ‖ in his turn, says : — "The stones of the fruit of the dome palm (Hyphæne Thebaica), after having been steamed, are pounded in a heavy mortar. Thus broken into small pieces, they somewhat resemble half-roasted chestnuts, and in this state they form excellent food for cattle."

Examination of the "Insoluble Residues" left after estimating Starch by Malt; and after treating the Woods with Hydrochloric Acid of about 2.5%, and with Acid of 1%.

In several instances the residues left after the woods had been acted upon by malt, or by the dilute acids, were tested for pentosans both by means of hydrochloric acid of 1% and by determining furfurol in the

furol. The properties of both bodies were described with a considerable degree of accuracy.

* Cited in Biedermann's Central-Blatt für Agrikultur-Chemie. 1894, **23.** 671.
† Rich, C. J., Memoir on the Ruins of Babylon. London. 1818, p. 59.
‡ In his book entitled, The Great Sahara. London. 1860, p. 154.
§ Chap. ix. (note on p. 140 of Vol. I, of the Leipsic edition).
‖ The Nile Tributaries of Abyssinia. London. 1867, p. 33.

residues either before or after they had been acted upon by the 1% acid, as will appear from the statements in the following list.

Pentosans (or Mannans) in Residues left after the action of Malt.

A. The bark of the Gray Birch tree felled in October gave 4.24% of "starch" when tested with malt extract, and there was got from the washed solid residue left after the action of malt 19.33% of furfurol, *i. e.*, the solid residue contained 35.56% of pentosans.

B. The outer wood of the Gray Birch tree felled in October gave 3.51% of "starch" to malt and the residue gave 17.75% of furfurol, *i. e.*, 32.66% of pentosans.

C. The outer wood of an Alder felled in January gave 3.04% of "starch," the residue therefrom being boiled with hydrochloric acid of 1% gave 14.72% of pentosans and the residue from the action of the 1% acid gave 6.75% of furfurol, *i. e.*, 12.42% of pentosans, all calculated in this case on the original dry wood.

D. Date Stones tested with malt extract gave (I) 5.44% and (II) 4.79% of "starch." The residue from No. I starch determination on being boiled with hydrochloric acid of 1% gave 11.65% of mannan and the residue from the 1% acid gave 3.38% of furfurol, *i. e.*, 6.22% of pentosans. All calculated on the original dry stones which of themselves had yielded 9.64% of pentosans when subjected to the furfurol test.

E. Apricot Stones tested with malt gave 1.46% of "starch" and the residue boiled with hydrochloric acid of 1% gave 14.07% of pentosans. The residue from the action of the 1% acid gave 9.57% of furfurol, *i.e.*, 17.61 of pentosans. All calculated on the original dry stones. The sum of the pentosans obtained from the malt residue (14.07 + 17.61 = 31.68) is almost as large as the quantity got, through furfurol, from the original wood (33.81%).

F. The residue left after the action of malt on Peach Stones on being treated with hydrochloric acid of 1% gave 6.67% of pentosans and the residue from the 1% acid gave 9.65 of furfurol, *i. e.*, 17.96% of pentosans. All calculated on the original dry stones.

Pentosans (or Mannans) in the Residues left after action of Hydrochloric Acid of about $2\frac{1}{2}\%$.

From the residue left after the action of hydrochloric acid of about 2.5% on the bark of the Gray Birch tree felled in May, there was obtained furfurol amounting to 6.53% of the original dry bark, *i. e.*, 12.02% of pentosans.

From the residue after the action of hydrochloric acid of about 2.5% on the bark of the Gray Birch tree felled in July, there was obtained

furfurol amounting to 5.97% of the original dry bark, *i. e.*, 10.98% of pentosans.

From the residue after the action of hydrochloric acid of about 2.5% on the outer wood of the Gray Birch tree felled in July, there was obtained furfurol amounting to 8.63% of the dry wood, *i. e.*, 15.87% of pentosans.

From the residue after the action of hydrochloric acid of about 2.5% on the inner wood of the Gray Birch tree felled in July, there was obtained 7.96% of furfurol, *i. e.*, 14.64% of pentosans, calculated on the original dry wood.

One residue left after the action of hydrochloric acid of about 2.5% on the outer wood of a Gray Birch felled in October, on being boiled for one hour with hydrochloric acid of 1% gave 0.88% of pentosans and the residue from the action of this 1% acid gave 4.63% of furfurol, *i. e.*, 8.53% pentosans, all calculated on the original wood. Another similar residue from the action of acid of about 2.5% on being boiled with acid of 1% gave 0.83% of pentosans and the residue from this action gave, in its turn, 4.23% of furfurol, *i. e.*, 7.78% of pentosans.

From the residue left after the action of hydrochloric acid of about 2.5% on the outer wood of a Sugar Maple felled in October, there was obtained furfurol amounting to 4.86% of the residue, *i. e.*, to 8.94% of pentosans : while the residue from the inner maple wood yielded 6.44% of furfurol or 11.85% of pentosans.

From the residue left after the action of hydrochloric acid of about 2.5% on Date Stones there was obtained furfurol amounting to 4.30% of the original dry stones, *i. e.*, to 7.91% of pentosans. In the experiment (page 396) where the stones themselves were distilled for furfurol 9.64% of pentosans were obtained.

From the residue left after the action of hydrochloric acid of about 2.5% on Apricot Stones there was obtained furfurol amounting to 6.95% of the original dry stones, *i. e.*, to 12.78% of pentosans.

From the residue left after the action of hydrochloric acid of about 2.5% on Peach Stones there was obtained furfurol amounting to 7.60% of the dry stones, *i. e.*, to 13.98% of pentosans.

Pentosans in the Residues left after action of Hydrochloric Acid of 1%.

From the residue left after the action of hydrochloric acid of 1% on the outer wood of the Gray Birch tree felled in October there was obtained furfurol amounting to 12.88% of the original dry wood, *i. e.*, to 23.70% of pentosans.

From the residue left after the action of hydrochloric acid of 1% on Peach Stones there was obtained furfurol amounting to 8.73% of the original dry stones, *i. e.*, to 16.06% of pentosans.

From the residue left after the action of 1% hydrochloric acid on Apricot Stones there was obtained furfurol amounting to 12.78% of the original wood, *i. e.*, to 23.52% of pentosans.

Wood Gum, so called. The method of preparing wood gum from sawdust as employed by Thomsen * which in its simplest form consisted in leaching the wood with ammonia water to dissolve albuminoids and coloring matters, digesting the residue with soda lye and mixing the filtrate with rather more than its own volume of alcohol, has been put to good use by many observers as a means of obtaining material for further study, though at its best it can hardly be classed as a quantitative method of analysis,† because of the fundamental difficulty that the alkali never dissolves out from the wood all the xylan which can be shown to be therein contained. It is to be remarked, however, that Thomsen's method is to be preferred to the rough and ready process suggested by Loew,‡ which consists simply in digesting the finely powdered wood with ten times its weight of soda lye of five per cent. and acidulating the filtrate with hydrochloric acid.

Misled by the apparent easiness of this plan I have applied it in a number of instances until convinced of its defects. The prime objection to Loew's plan is the liability that in the absence of alcohol the wood gum will not be precipitated, or at the least will not be precipitated completely at the moment when the alkaline liquid is acidified. The difficulty is aggravated doubtless by the fact that the original alkaline liquid has to be diluted to a considerable extent with water in order that it may be filtered. But, as was noticed by Thomsen,§ wood gum is precipitated by dilute acids less quickly and probably less completely than it is precipitated by alcohol. He remarks that on supersaturating the alkaline solution with an acid a precipitate appears after a time, but that the precipitate appears immediately when the liquid is mixed with an equal volume of alcohol. He observes also that Poumarède and Figuier,‖ as long ago as 1847, called attention to the fact that it is through the influence of the saline matter which is formed

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* Journal für praktische Chemie. 1879 [N. F.], **19.** 159–163.
† Compare Hoffmeister, Versuchs-Stationen. **48.** 406, 409.
‡ See Okamura, in Versuchs-Stationen. **45.** 433, 437.
§ Journal für praktische Chemie. [N. F.] **19.** 150, 166.
‖ Journal für praktische Chemie. **42.** 29; [N. F.] **19.** 148.

on neutralizing the alkaline solution, that the colloid wood gum is thrown down.

I can myself bear witness that it happens occasionally when an alkaline solution of wood gum is acidulated that no great amount of precipitate will appear until after the lapse of some time when a mass of it will fall all at once as if from a supersaturated solution. Gudkow,[*] when working upon wheat bran and the excrement of a bran-fed pig, noticed that while considerable quantities of pentosans could be dissolved from these materials by dilute potash lye no precipitate was produced on acidulating the alkaline solutions. Hoffmeister [†] in his turn encountered this difficulty and insisted that the addition of alcohol to the acidulated liquid is necessary in order to insure complete precipitation of the gum. Once down, the precipitate might be washed with cold water, but, as Hoffmeister has said, in order to avoid loss a sufficient quantity of alcohol must be added at once, at the time of neutralization. In any event, wood gum, even that prepared by Thomsen's method can hardly fail to contain more or less of the lignic acids of Lange and of the " cellulose gum " of Hoffmeister. For the rest, it is notorious that wood gum distilled with hydrochloric acid gives less furfurol than should be given if the material were pure xylan,[‡] and that less xylose than theory requires is yielded by wood gum when subjected to hydrolysis.[§]

Here follows a statement of results obtained in several instances in which impure wood-gum was precipitated in the rough manner suggested by Loew.

Kind of Wood.	Per cent of wood gum in wood dry at 100° C.		
	Inner Wood.	Outer Wood.	Bark.
Gray Birch felled in May	14.29	14.41	..
" " " " October	13.11	13.54	6.77
Sugar Maple " " "	..	..	4.48
Alder felled in January	19.36	15.00	11.83
Date Stones			8.85

Cellulose. Several estimations of the " cellulose " in the woods under examination made by the Weende method — which consists essentially in acting upon the powdered wood with hot dilute acids and alkalies used alternately — gave the following results : —

[*] Zeitschrift für Chemie.   1870 [N. F.], **6.** 362, 364.
[†] Landw. Jahrbücher.   1888, **17.** 251.
[‡] Flint and Tollens, Versuchs-Stationen.   **42.** 406.
[§] Tollens, Handbuch der Kohlenhydrate.   **2.** 202.

Kind of Wood.	Per cent of " crude fibre " found by the Weende method, (wood dry at 100° C.).		
	Inner Wood.	Outer Wood.	Bark.
Gray Birch felled in May 54.43		55.23	..
" " " " October		(I.) 54.02	..
" " " " " 52.52		(II.) 51.57	..
Alder felled in January 48.32		48.04	29.82
Date Stones (I.) 26.08			
" " (II.) 24.74	From Bulletin of the Bussey		
Peach " 74.77	Institution. **1.** 375.		
Prune " 54.74			

Nothing could illustrate better the inadequacy of the Weende process, in so far as woods are concerned, than the fact that on testing several of these samples of crude fibre for furfurol each of them yielded more than 20% of it, *i. e.*, the crude fibre consisted to the extent of considerably more than one-third its weight of pentosans.   A still larger percentage of furfurol was obtained from the crude fibre of alder wood than was got from the crude fibre of birch.   These results simply corroborate those of previous observers,[*] and it may be said to be admitted nowadays that the so-called crude fibre of the agricultural chemists always contains pentosans which are capable of yielding furfurol when distilled with strong acids.   This remark is true not only of fibre obtained by the Weende method as above, but of that obtained by the processes of F. Schulze and Hoffmeister (treatment with potassium chlorate and nitric or hydrochloric acids) which yield fibre that is by no means free from pentosans.[†]

On examining paper-pulp that had been prepared commercially from spruce or pine wood, Flint and Tollens [‡] obtained enough furfurol to show 5.51% of pentosans in dry pulp prepared by the sulphite process and 5.61% of pentosans in dry pulp prepared by means of soda.   These results show celluloses so much less strongly contaminated with pentosans than are the crude fibres ordinarily obtained by chemists in analytical laboratories that I have been led to give some attention to an examination of the

[*] Compare Winterstein, Zeitschrift für physiologische Chemie. **17.** 385, and Goetze and Pfeiffer, Versuchs-Stationen. **47.** 75. See also Meissner, Shepard, Dietrich and Koenig, Versuchs-Stationen. **13.** 222.

[†] E. Schulze, Zeitschrift für physiologische Chemie. **16.** 430, 432; and Tollens's Handbuch der Kohlenhydrate. **2.** 203. See also Winterstein, Zeitschrift für physiologische Chemie. **17.** 385, 387.

[‡] Versuchs-Stationen. **42.** 402, 403, 407.   *Cf.* Handbuch der Kohlenhydrate. **2.** 253, 256.

process of determining cellulose, as proposed by Lange,[*] which consists in fusing with solid caustic potash the wood or other matter to be analyzed. As will be seen below, this attractive process has proved to be much less efficient than it seemed to promise. It has failed signally to effect a complete separation of pentosans from the cellulose proper.

As employed in this laboratory the process of Lange may be described as follows: — Five grm. portions of finely-ground, air-dried wood are digested for twenty-four hours, with occasional stirring, in soda lye of 5% to remove wood gum, fat, albuminoids, coloring matters, etc. The supernatant liquid is syphoned off as completely as possible from the undissolved wood, the latter is transferred to a tubulated retort, and thirty grm. of solid potassium hydrate are put into the retort which is then heated in a paraffine bath, gently at first, but after a time the heat is increased very slowly and gradually, though steadily, in such wise that at the end of an hour the thermometer in the bath shall have risen to 180° C. By proceeding in this way all trouble from frothing or bumping is avoided. The retort is maintained at the temperature of 180° until the mass has become dry, when it will be found to all appearance to be thoroughly decomposed. The temperature is allowed to fall to 80°, the cake is dissolved in hot water, an excess of dilute sulphuric acid is added, then soda lye to slight alkalinity and the cellulose is finally collected on a weighed filter and washed with hot water, alcohol, and ether.

The purpose of the digestion in soda lye before the fusion is to facilitate the final filtration of the cellulose. Thanks to the removal of disturbing gummy and slimy matters, the final filtration now becomes not only possible but comparatively speaking easy. This digestion with soda lye might, perhaps, be made to serve also incidentally as a means of collecting the "wood-gum." The results given in the following table were obtained by this method, after some mechanical difficulties, which were encountered at first, had been overcome: —

Kind of Wood.	Per cent of " cellulose " found by Lange's (KHO) method, (wood dry at 100° C.).	
	Outer Wood.	Bark.
Gray Birch felled in October	53.23	..
Sugar Maple " " "	57.24	40.75
Peach Stones	47.14	'
Apricot "	52.93	
Date "	31.09	
Ivory Nut	(I.) 29.58	
" "	(II.) 29.21	

[*] Zeitschrift für physiologische Chemie. **14.** 283, 328.

On examining this so-called cellulose, left after the fusion of wood with caustic potash, it appeared that it was by no means free from pentosans. Some of the cellulose thus obtained from the outer wood of the gray birch felled in October was boiled for one hour in hydrochloric acid of 1% and there was obtained sugar enough to amount to 11.91% of pentosans in the cellulose or to 5.88% in the original dry wood, and on distilling for furfurol the residue left after the action of the 1% acid, there was found 2.24% of it, *i. e.*, enough to amount to 7.72% of pentosans in the cellulose or 4.12% in the original wood. By adding together the quantities of pentosans obtained by the acid and by the furfurol it appears that the dry " cellulose " contained 19.63% of these substances.

So too, on boiling the " cellulose " from the outer wood of the sugar maple with 1% hydrochloric acid there was obtained 12.08% of pentosans in this cellulose or 6.71% in the wood.

The cellulose from the ivory nut on being boiled for one hour with hydrochloric acid of 1% gave sugar enough to amount to 9.94% of paramannan in that cellulose or to 2.98% in the original dry nut.

It should here be said that Cross and Bevan * have expressed their disapproval of Lange's process in the following terms. " Quantitative results obtained by this method have only a limited value; and, as estimations of " cellulose," are subject to large and variable errors." And yet — in view of the fact that the fusion with caustic potash removes lignic acids from the materials operated upon — it is probably true that Lange's method is the best method yet devised for determining cellulose in the ordinary run of coarse foddering materials, provided that a correction be made by estimating pentosans (by way of furfurol or by phloroglucin) in the so-called cellulose and subtracting the weight of the pentosan from that of the " cellulose " left by the potash, which is in this case simply a mixture of cellulose and a pentosan, and not the mixture of cellulose, pentosans and " lignin," which is so often encountered in the ordinary conduct of fodder analysis. This method of procedure would not be applicable, however, for the analysis of the ivory nut and other palm seeds, or products from these seeds, for, as has been set forth above and

* In their book entitled " Cellulose," page 23.

as was shown also by E. Schulze * in the case of the coffee bean, a single fusion with caustic potash is not competent to remove from the palm-cellulose all the paramannan which is admixed or combined with it. Attempts to overcome this difficulty have been made by Gilson,† who dissolved in Schweizer's reagent the crude fibre obtained from the coffee bean and threw down the real cellulose from this solution by means of a current of carbonic acid gas. E. Schulze ‡ also has analyzed the mixture approximately by hydrolizing the crude fibre and adding to the solution of dextrose, mannose and xylose thus obtained enough phenyl-hydrazin acetate to throw down the mannose. The difficultly soluble mannose-hydrazon thus formed was collected on a tared filter and weighed. Xylan might be determined, as furfurol, in a special portion of the crude fibre and the sum of the weights of the mannose and xylose be then subtracted from the total weight of the mixed sugars obtained by hydrolizing the fibre.

It is of interest to compare the above given determination of cellulose in date stones by Lange's KHO process with other determinations of crude fibre made by me many years ago § in this material by the Weende process, for where Lange's process shows 33.42% of cellulose, the Weende process had shown 26.08% and 24.74%. The explanation of this disagreement would seem to be that the repeated action of the dilute acid and alkali in the Weende process had dissolved out the paramannan from the date stones more completely than a single fusion with caustic alkali could do. A similar remark will apply to the so-called cellulose obtained from the ivory nut by Lange's KHO process. For in this case also it is evident that a very considerable part of the paramannan in the nut was not made soluble by the single fusion with potash. This question of the amount of real cellulose in the ivory nut has been much debated both by chemists and botanists. In several instances thoroughly trustworthy analysts (S. W. Johnson, among others) have reported as little as 5 to 7.5% of crude fibre in the ivory nut, while other observers have noted quantities amounting

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* Landwirthschaftliche Jahrbücher. 1894, **23**. 26.
† Tollens's Kohlenhydrate. **2**. 250.
‡ Zeitschrift für physiologische Chemie. **19**. 58.
§ Bulletin of the Bussey Institution. **1**. 373.

to 16, 21, 32, 73, 75, 76 and 81%.* The explanation of this
conflicting testimony is doubtless that in some instances the para-
mannan, of which the nuts consist for the most part, was hydro-
lized and dissolved well nigh completely by the alternate action of
dilute acid and alkali, while in other instances it was but little
acted upon. Indeed, Hoffmeister † operating upon "cellulose"
which had been prepared by his process (potassium chlorate and
hydrochloric acid) from the ivory nut, found that he could dissolve
more than 87% of this "cellulose" in weak soda lye (of from 1%
to 5%) by applying the solvent in repeated portions. It is note-
worthy also that Koch, and Winterstein,‡ have remarked that a
larger quantity of xylan can be dissolved out from the "cellulose"
of woods after the action of F. Schulze's mixture of nitric acid
and potassium chlorate than will dissolve before the application of
this reagent.

On the other hand, peach stones gave by the Weende method
a very large percentage of crude fibre (74.77%) while there was
found in another sample, by Lange's K H O process, but little more
than 47%. I hope to study the question as to what influence,
if any, the presence of "lignin" in the peach stones may per-
haps have had to hinder the action of the dilute Weende reagents.

On attempting to collate in the form of a complete analysis any
of the results of the examination of woods, as here recorded, it
will appear at once that the sum of the several constituents in any
given wood, as above determined, are far enough from expressing
the total composition of the wood. On the contrary, the results
teach an emphatic lesson as to the limitations of the analytical
processes employed, and they point to the urgent need there is of
devising new and improved methods. As an example, the analy-
sis of the outer wood of the birch tree felled in October may be
stated as follows :—

* Compare Reiss's discussion of the question in Landwirthschaftliche Jahr-
bücher. 1889, **18.** 743, 745.
† Landwirthschaftliche Jahrbücher. 1889, **18.** 772.
‡ Zeitschrift für physiologische Chemie. **17.** 396.

The Outer Wood of a Gray Birch Tree felled in October contained
(dry at 100° C.) per cent. of,

"Starch" (by malt)	3.51	. . . .	3.51
Pentosans shown by hydro- chloric acid of 1%, less 3.51% of "starch"	8.74	Pentosans shown by fur- furol in residue from action of malt	82.66
Pentosans shown by furfurol in residue from action of 1% H Cl	23.70		
Cellulose (by K H O), after subtraction of pentosans found in the crude fibre . .	43.83	. . . .	43.83
Ash	0.36	. . . .	0.36
Albuminoids (N [0.52] × 6.25)	3.25	. . . .	3.25
Fat (ether extract)	2.53	. . . .	2.53
"Lignic acids"* and other undetermined matters, *i. e.*, "loss"	14.08	. . . .	13.86
	100.00		100.00

* NOTE. — It is of interest to remark that Lange † found 12% and 14% of his "lignic acids" in beech wood and oak wood respectively. Though from the severe chemical treatment (fusion with caustic potash) to which these substances have been subjected, it is to be suspected that they are in some degree products of the decomposition of matters in the wood rather than actual constituents of the original wood, it is to be noted none the less that the lignic acids of Lange, like the old "lignin" of several earlier experimenters, contain a higher percentage of carbon than is contained either in cellulose or in xylan, whence the conclusion that they are derived from another "encrusting matter" than xylan. Unfortunately, much confusion still prevails as to the use of the word lignin which was often applied formerly to a mixture of lignic acids and xylan, or even in some instances to xylan alone. Thus, as a basis for the perplexing statement of some authors that wood may consist to the extent of one-half or one-third its weight of "lignin," it seems plain that xylan and lignic acids must have been counted in together.

I am indebted to my assistant, Mr. J. M. Tilden, for much help in carrying out the details of this research.

† Zeitschrift für physiologische Chemie. 1890, **14.** 26.

No. 36. — *Laboratory Notes.* By F. H. Storer, Professor of Agricultural Chemistry.

A. *Doty Birch Wood yields little Wood-Gum.* — Since the evidence thus far accumulated tends to show that the hemicellulose xylan (wood-gum) in the trunks of trees is comparatively speaking difficult of digestion and less active, physiologically speaking, than the true cellulose with which it is accompanied and combined it might well be possible that doty, decaying or decayed wood should yield more wood-gum to alkaline lyes than can be obtained from the sound wood.

On subjecting this idea to the test of experiment it was found to be untenable, at least in so far as concerns doty wood of the Gray Birch (Betula populifolia of Aiton).

Two samples of dead and decaying birch wood were collected in January. The first specimen was an excellent example of doty wood. It was from the trunk of a tree thirteen inches in circumference, the outer bark of which was in place and undecomposed. The wood was almost white, as to its color and looked like pith; it was light and punky and so brittle that when dry it could readily be crumbled between the fingers. Although the shape of the original bough was retained, the material had lost all semblance of strength or solidity excepting at the innermost heart which consisted of a thin core of tolerably firm wood.

The second sample was much more thoroughly decayed than the first. It was from a bough three inches in diameter. On removing the outer bark, which was well preserved, there was found within a soft spongy mass of dark, decayed wood which crumbled to powder readily between the fingers. All parts of the material seemed to be equally decayed, though at some time it had been infested with worms whose borings could readily be traced since they were filled with a brown powder, *i. e.*, the indigestible matter rejected by the worms. This powder was scraped out from the worm-holes and rejected, while the rotten wood proper was dried and powdered.

It is to be remarked of these two examples that the first was a much better specimen than the second, and that the results obtained on analyzing the first sample were more intelligible and more satisfactory. Had it not been that the second sample yielded a fairly

large quantity of furfurol it would have been said at once that the "wood-gum" obtained from it must have consisted in some part of humic acids.

For the sake of comparison, analyses were made of wood from the outer portion (free from outer or innner bark) of the trunk of a birch tree felled in May, and also from a white pine board of unknown origin.

As will be seen from the table, sound birch wood gave up much more wood-gum to alkalies and more furfurol also when distilled with hydrochloric acid of 1.06 sp. gr. than could be got from the doty or the decayed wood.

There was obtained from the materials, dry at 100° C. : —

	Doty Birch Wood.	Decayed Birch Wood.	Sound Outer Wood of Birch felled in May.	Wood of the White Pine (Pinus Strobus L.).
Cellulose (by Lange's KHO process) . . .	35.19	11.77	46.73	55.10
Lignic Acids (do.) . .	14.67	12.83	5.43	21.51
Wood-Gum	3.46	9.54	12.81	0.96
Furfurol	0.94	6.84	19.62	4.66
Pentosans, calculated from the Furfurol, i. e. furfurol × 1.84	1.73	12.60	36.10	8.57

Wood-gum was determined by Thomsen's * method. The other estimations were made by the methods of analysis described on pages 387, 404 of this Bulletin.

The comparatively large quantities of "lignic acid" (of Lange) found in the decaying and decayed wood is noteworthy and the natural presumption would be, of course, that this constituent — or the substance from which it is derived — must decay less rapidly than either cellulose or xylan. But it should be remembered that our methods of analysis are by no means sufficiently accurate to justify any one in drawing hard and fast conclusions from the results of a few tests. The anomalous behavior of the wood-gum obtainable from pine trees — to be mentioned below, in Note C— should inculcate caution in reasoning upon a point like this.

B. *Estimations of Cellulose, Lignic Acids, Xylan and Wood-Gum in Peach Stones.* — Dry, pulverized peach stones, *i. e.* the hard outer shells or covering of the kernels, when tested by the

* Journal für praktische Chemie. 1879 [N. F.], **19.** 159.

ordinary Weende method of analysis, gave 74.77% of "crude fibre."* Three other samples, after having been digested in ammonia water for 24 hours and washed with water until the filtrate no longer gave an alkaline reaction, were fused with caustic potash according to Lange† and the mixture was kept for an hour at 180° C. There was obtained 47.14%, 44.75% and 49.95% respectively of "cellulose." In the last two instances, dilute sulphuric acid and alcohol were added to the filtrates from cellulose to throw down Lange's "lignic acids" and there was obtained of this substance 17.14% in the one case and 13.54 in the other.

On distilling the 13.54% sample of lignic acids with hydrochloric acid for furfurol there was obtained 7% of it, equal to 12.88% of pentosans in this lignic acid or to 1.75% of pentosans in the original peach stones.

On distilling the 44.75% sample of cellulose with hydrochloric acid for furfurol there was obtained 24.59% of it in that cellulose, equal to 45.23% of pentosans in the cellulose, or to 11% of furfurol and 20.24% of pentosans in the original peach stones. In this instance it will be noticed there was no preliminary leaching of the peach stones with soda lye to remove wood-gum.

A portion of the 49.95% sample of cellulose was moistened and fused anew with a fresh quantity of caustic potash which was held at 180° for an hour, as usual, and there was recovered 93.94% of it as cellulose and 5.91% as lignic acids. Still another 15 grm. sample of the powdered peach stones, after having been digested with ammonia water and washed, as before, was left to soak during 24 hours in the cold with ten times its weight of a 5% solution of caustic soda. Wood-gum was precipitated from this solution by means of dilute hydrochloric acid and alcohol, and cellulose and lignic acids were determined subsequently in the matter insoluble in soda lye, by fusing this residue with caustic potash, after Lange. There was found 2.99% of wood-gum, 20.45% of lignic acid and (somewhat remarkably) 66.72% of cellulose, which on being distilled with hydrochloric acid gave 10.77% of furfurol, equal to 19.82% of pentosans.

Yet another sample of the peach stones, after treatment with ammonia water, was digested for 24 hours in hot 5% soda lye, in

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quantity similar to that used in the cold, and the analysis was proceeded with as before. There was found in this case 3.37% of wood-gum which was but little more than had been dissolved out by the cold soda lye, and 25.55% of lignic acids, *i. e.* more than was got in the preceding trial, and 49.47% of cellulose.

The amount of wood-gum obtained from the peach stones, 2.99% and 3.37%, is noticeably small in view of the fact, that on distilling the powdered stones for furfurol 15.02% of this substance was obtained, which is the equivalent of 27.64% of pentosans.

With the exception of the anomalous result (66.71%) in the case where the material had been digested in cold soda lye, before the fusion with caustic potash, it will be seen that the percentage of " cellulose " obtained from peach stones by Lange's method is a fairly constant quantity, though the large proportion of furfurol obtained on distilling this so called cellulose with hydrochloric acid goes to show that the material is far enough from being pure. The indications are that it is combined with a large proportion of pentosans. It will be noticed also, that while, generally speaking, in the foregoing trials a low percentage of cellulose is accompanied with a high percentage of lignic acids — thanks probably to the more or less effective action of the caustic potash in the different instances — it cannot be said that the quantities of cellulose and lignic acids are complementary. On adding together the percentages of cellulose, wood-gum and lignic acids, it will be seen that the sums total differ to no inconsiderable extent in the several instances. It would appear that more or less of the original material has actually been destroyed, *i. e.* dissipated by the hot alkali.

It is worthy of remark that on treating the peach stones with a mixture of nitric and sulphuric acids, less cellulose was obtained than was got by means of Lange's process. Thus, a quantity of powdered peach stones (15 grm.) was digested, according to Lifschütz, for 16 hours at a temperature of 45° to 50° C. with 10 or 12 times its weight of a mixture of 1 volume of concentrated sulphuric acid and 3 volumes of nitric acid of 1.2 sp. gr., and then washed successively with cold water, hot water, a warm dilute solution of sodium carbonate, and again with hot water. On drying and weighing this cellulose it was found to amount to

20.63% of the dry peach stones. But in one of the previous trials 24.51% of pure cellulose had been indicated by subtracting from the crude cellulose of Lange the pentosans therein contained.

To another (5 grm.) sample of the peach stones 50 cc. of nitric acid of 1.345 sp. gr. were added, the mixture was heated on a boiling water bath in a dish with a reflux condenser and from time to time crystals of potassium chlorate were thrown into the liquid. As was to have been expected, the action of the mixed chlorate and nitric acid was emphatic. The cellular structure of the cellulose was practically destroyed and the appearance of the undissolved matter answered very well to the description given by Sacc * of his " artificial pectic acid," i. e. the oxycellulose of more recent observers. On washing, drying and weighing this doughy mass it was found to amount to 15.20% of the dry peach stones, and on distilling it with hydrochloric acid for furfurol there was obtained 26.62% of this substance. If this large amount of furfurol had really been derived not from oxycellulose but from pentosans, contained in constituents of the original peach stones which had escaped the destructive action of the oxydizing agents, it would appear that the matter weighed as cellulose (oxycellulose) must have contained 48.98% of pentosans. In other words, it might be said that the above mentioned 15.20 parts of cellulose (oxycellulose) consisted of 7.45 parts of pentosans and no more than 7.75 parts of real cellulose.

It would appear in any event that the hard, compact ligneous peach stones probably contain a smaller proportion of true cellulose than is contained in various kinds of woods. Thus, there was found by Lange's process in the wood of a sugar maple felled in October 57.24% of cellulose, while the wood of another sugar maple felled in May gave 57.42% of cellulose and 9.11% of lignic acids. This cellulose on being distilled with hydrochloric acid gave 13.95% of furfurol, equal to 25.67% of pentosans in the cellulose. When referred to the actual wood from which this cellulose was derived, the figures become 8.01% of furfurol and 14.74% of pentosans. When a sample of the wood itself was distilled directly with hydrochloric acid there was obtained 10.47% of furfurol, equal to 19.25% of pentosans. On subtracting from the " cellulose " found (57.42%) the pentosans that were con-

* Gmelin's Handbook. **15**. 413.

tained in it there is still left the number 42.68 as the percentage of real cellulose in the maple wood. In another trial with the May maple there was found 61.44% of cellulose and 7.46% of lignic acids, but these determinations were manifestly faulty, because some particles of wood, thrown up by the frothing of the fused mass, escaped from the action of the melted potash and imparted a brown color to the washed cellulose. On oxydizing the maple wood with nitric acid of 1.15 sp. gr. there was obtained mucic acid enough to represent 1.89% of galactan.

The outer wood, devoid of bark, of a gray birch tree felled in May was found to contain 46.73% of cellulose, 12.81% of wood-gum and 5.44% of lignic acids; while in another trial there were found 49.74% of cellulose and 8.83% of lignic acids. From the outer wood of a gray birch felled in October there was obtained 13.54% of wood-gum and 53.23% of cellulose, which contained 19.63% of its weight of pentosans. Hence the real cellulose in the wood was $53.23 - 10.45 = 42.78\%$.

Wood of the white pine yielded 55.10% of " cellulose," 21.51% of lignic acids and 0.96% of wood-gum, as has been said. There was obtained also, on oxidizing the pine wood with nitric acid of 1.15 sp. gr., enough mucic acid to represent 1.38% of galactan.

C. *Cold dilute Alkaline Solutions dissolve very little Wood-Gum from the trunks of Coniferous Trees.* — The fact, as stated in the table in Note **A**, that only a very small quantity of wood-gum is obtained on leaching pine wood with 5% soda lye has been observed repeatedly. Yet, in spite of its great theoretical interest and importance, it appears never to have received the recognition and attention which it deserves. It is not easy of explanation in view of the other fact noticed by Hoffmeister*.that an abundance of wood-gum can be obtained from pine and spruce wood by first soaking them for 24 hours in cold concentrated hydrochloric acid, then washing with water and leaching with 5% soda lye.

In proof of the small quantity of wood-gum obtainable by the direct action of alkaline solutions, Thomsen† says that unlike the woods of deciduous trees, which give up to dilute soda lye from 8 to 26% of wood-gum, fir wood is hardly at all acted upon by

* Landwirthschaftliche Jahrbücher. 1888, **17**. 259.
† Journal für praktische Chemie. [N. F.] **19**. 147.

soda lye. He obtained less than 0.8% from spruce wood and less than 0.5% from fir wood, and half of this quantity was ashes. "In these coniferous trees," he says, "wood-gum appears to be absent or at the least to be present in very minute quantities." Koch [*] in his turn says : — No wood-gum can be got from the wood of coniferous trees or from vegetable tissues that are free from lignin. The small quantities of this substance which appear to be got from coniferous trees and from some tissues by means of soda lye may be regarded as products of the decomposition of cellulose. On macerating pure cellulose with 10% soda lye almost half its weight goes into solution in the form of a soda-compound, of the composition $4 C_6H_{10}O_5 + NaHO$, which separates out on adding alcohol.

Wheeler and Tollens [†] got "very small quantities of wood-gum from fir wood," i. e. no more than 0.4%, though they found that the wood itself yielded xylose on hydrolysis. From jute they got 1.73% of wood-gum, and they obtained xylose also by hydrolyzing the jute itself.

Hoffmeister [‡] soaked powdered pine and fir wood in ammonia water (after Thomsen) and in other instances he boiled the woods in water, and then treated them with 5% soda lye. But, as he says, next to nothing went into solution in the soda ; even stronger soda lye up to 20% dissolved nothing, i. e. at the ordinary temperature of the air.

Tauss [§] in his elaborate experiments on the behavior of woods and cellulose, when treated with soda lye at high temperatures, found that fir wood on being boiled for three hours, under the ordinary atmospheric pressure, in three successive portions of soda lye of 1.043 sp. gr. (3% NaHO), dissolved to the extent of 28% of the air dried wood, but that alcohol precipitated nothing from this solution, while acid precipitated 1.31% of the air dried wood.

Fir wood similarly treated with lye of 1.09 sp. gr. (8% NaHO) dissolved to the extent of 49% its weight, but only some traces of

[*] Berichte der deutschen chemischen Gesellschaft. **20.** (Ref.) p. 145.

[†] Berichte der deutschen chemischen Gesellschaft. **22.** 1046; Annalen der Chemie und Pharmacie. **254.** 324.

[‡] Landwirthschaftliche Jahrbücher. 1888, **17.** 259; 1889, **18.** 772.

[§] Dingler's Polytechnisches Journal. 1890, **276.** 418.

precipitates were thrown down from the solution either by alcohol or acids.

Fir wood similarly treated with soda lye of 1.162 sp. gr. (14% NaHO) dissolved to the extent of 35.5%. From this solution alcohol threw down 4.8% of the air dried wood and acid threw down 2%.

On repeating these experiments under pressures of 5 and 10 atmospheres the following results were obtained: — Soda lye of 1.043 sp. gr. under a pressure of 5 atmospheres dissolved 51% of the air dried fir wood. Alcohol gave no precipitate in this solution, but acid threw down 16% of the wood. Under a pressure of 10 atmospheres, the lye of 1.043 sp. gr. dissolved 70% of the wood, and from this solution alcohol threw down some traces of a precipitate, while acid threw down 17%.

Soda lye of 1.09 sp. gr. under a pressure of 5 atmospheres dissolved 76% of the wood, and alcohol produced a small precipitate in this solution amounting to 2% of the wood, while acid threw down a precipitate equal to 16% of the wood. Under a pressure of 10 atmospheres the lye of 1.09 sp. gr. dissolved 82% of the air dried fir wood, and in this solution alcohol threw down 2% and acid 25% of the weight of the wood.

Soda lye of 1.162 sp. gr. under a pressure of 5 atmospheres dissolved 92% of the fir wood, i. e. almost the whole of the wood. From this solution alcohol threw down 27% and acid 25% of the weight of the wood.

It is noticeable of all the woods, i. e. both fir and beech and of cellulose itself that the action of strong lyes under high pressures is deep-seated. Tauss found that soda lye of 1.162 sp. gr., under a pressure of 5 atmospheres, dissolved 77% of air dried Swedish filter paper. Lye of 1.09 sp. gr., acting under a pressure of 10 atmospheres, dissolved 50% of the paper and from this solution alcohol threw down a precipitate equal to 10.3%. So with the fir wood, it will be noticed that matters precipitable by alcohol began to be obtained in abundance only when the wood was treated with strong lye under high pressure, although the wood itself was dissolved to no inconsiderable extent by weak lyes at high temperatures and pressures.

Beech wood, on the contrary, yielded an abundance of wood-gum to hot weak lyes under the ordinary pressure. Indeed, the

yield of wood-gum was less at high pressures than at low, apparently because of the destruction of some constituents of the wood by the extremely hot, strong alkali.

In the light of what has been learned hitherto, the point of especial interest is the fact observed by Hoffmeister, as just now said, that after soaking pine, spruce or fir wood in cold, strong hydrochloric acid, an abundance of what appears to be wood-gum can be dissolved out from these woods by means of dilute soda lye acting at the ordinary temperature; the inference being that the strong acid has acted in some way to set free or loosen the xylan from its combinations in the wood so that it can now be dissolved by the caustic soda.

There appear to be two reasons why the remarkable facts here stated have received comparatively little attention. First : Numerous indirect estimations of xylan in coniferous woods have been made by distilling the wood with hydrochloric acid for furfurol and calculating from this product the corresponding amount of xylan which is often found to be large. The results obtained in this way have been set down in the text-books in the same category with those obtained by the direct precipitation of wood-gum from the woods of deciduous trees. Second: Some rather confused results of Wieler,* who obtained no inconsiderable quantities of mixed wood-gum and albuminoids from pine wood, have been accepted as if they contradicted the statements above set forth. But it is safe to say that Wieler's work cannot properly be regarded as of the same convincing character as that of Thomsen, Koch, Hoffmeister, Tollens, and Tauss.

D. *Not much Wood-Gum is obtainable from the Strawberry.* — The high degree of interest which attaches to the question, What is the function or purpose of the xylan that is found in plants? has led many chemists to devote their attention to the estimation of this substance in a great variety of vegetable matters. Many efforts have been made to determine what particular tissues contain the largest proportion of pentosans and to discover those plants or parts of plants from which the pentoses, and especially xylose, can be obtained most readily and most abundantly. One noteworthy result of this quest is the observation made by Pro-

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* Die landwirthschaftlichen Versuchs-Stationen. **32.** 338.

fessor Stone that corn cobs contain much xylan and that an abundance of xylose can readily be obtained from this source in a condition of exceptional purity.

In casting about for other instances, analogous to that of the corn cob, it was suggested to me that it might perhaps be worth the while to test the strawberry. On proceeding to do so, the following results were obtained. The dry matter in a sample of sound, southern strawberries purchased in Boston early in May yielded : —

Wood-gum 0.38
Furfurol 3.52
Pentosans calculated from the furfurol 6.48
"Sugar," stated as dextrose, consisting of a mixture of levulose and dextrose obtained by leaching the fruit with boiling water and heating the filtrate with HCl 22.96
The residue insoluble in boiling water was hydrolyzed with H_2SO_4 of $2\frac{1}{2}\%$; it yielded "sugar" enough to amount to 3.27% of xylose in the dry fruit, or in terms of xylan . . .   2.88
By treatment with HNO_3 of 1.15 sp. gr. and weighing the mucic acid formed there was found of galactan 1.74

Though familiar with Professor Stone's analyses of many kinds of strawberries, as published in volume **3**, page 257 of "Agricultural Science," I had forgotten that he had also tested the strawberry for pentosans * and had obtained from the pulp of the fruit 1.95% of furfuramid which as he shows would be equal to rather more than 3.29% of pentosans. In corn cobs, on the contrary, he found 8.16% of furfuramid or 13.77% of pentosans.

That the sugar in the strawberries which is set down in the table as if it were all dextrose was really a mixture of levulose and dextrose was shown by the fact that its specific rotation at 20° C. was found to be $[a]_p$ — 42.68.

It is noticeable also that much more sugar has been found both by Stone and by European observers in the fully ripened fruit examined by them than was obtained from my sample which had been brought — probably some hundreds of miles — from the South. In 20 different varieties of strawberries examined by Stone the lowest percentage of sugar (stated as dextrose) in the dry fruit was 52.45, the highest was 69.31 and the mean was 57.60. The average of 33 European analyses shows 50.89% of

* American Chemical Journal. 1891, **13.** 77.

total sugar (dextrose) in the dry fruit. This really enormous proportion of saccharine matter is the more remarkable when it is considered that all the seeds of the fruit were present in the matter examined; none of them had been removed in the process of drying. As Stone has remarked, dried strawberries might be made to serve many useful purposes were it not for the fact that it is far from easy to dry this fruit rapidly or cheaply.

E. *Quære:* — *As to the presence of Xylan in the membranous covering of the Starch Grain?* — Many distinguished observers have affirmed while others have denied the existence of cellulose in or upon the starch grain. The chief reason for the affirmation seems to be the visible presence upon the grains of a membranous covering, somewhat less soluble than starch, which may be isolated by the exhibition of appropriate solvents, while the denial is based on the fact that the membrane dissolves rather easily in hydrolytic agents, *i. e.* much more readily than cellulose is seen to dissolve in ordinary experience.

But starch on being distilled with hydrochloric acid of 1.06 sp. gr. always yields a certain small proportion of furfurol. In this laboratory as much as 1.2% of it have been obtained from maize starch, which would be the equivalent of some 2% of pentosans in that starch, and it seems more than probable that this furfurol must be derived from the membrane of the starch grains rather than from the starch itself. Hence the inference that the supposed " cellulose " of starch may really be a compound of xylan — possibly of xylan and galactan? It is to be noted withal that there is a marked difference between starch and a number of common organic substances, in that while small quantities of furfurol are obtainable from starch and from the purer kinds of cellulose also — such as cotton[*] and Swedish filter paper — practically no furfurol at all can be got from albuminoids, fats, etc. Günther, de Chalmot and Tollens[†] obtained only imponderable traces of fur-

[*] According to Cross and Bevan — in their book entitled "Cellulose," London, 1895, p. 255 — the ordinary bleached celluloses of the cotton group all give a small proportion of furfurol (0.3 to 1%) on being boiled with hydrochloric acid of 1.06 sp. gr.

Suringer and Tollens (Journal für Landwirthschaft. 1896, **44**. 355) also obtained but little furfurol from cotton.

[†] Berichte der deutschen chemischen Gesellschaft. 1892, **25**. 2571.

furol on distilling casein and flesh, and Düring * has corroborated
these observations as regards albumin, casein and fibrin.   From
fats also, whether of animal or vegetable origin, he got no furfurol
and only very small quantities were obtained from cotton, Swedish
filter paper and potato starch.

In this laboratory, no furfurol has been obtained on distilling
gelatin, rosin, paraffin, and tannic acid with hydrochloric acid of
1.06 sp. gr., while a specimen of pith (" Hollundermark ") from
the European elder (Sambucus) gave 0.68% of furfurol or 1.25%
of pentosans.

F. *Analysis of a Sample of Ashes left on burning the Bamboo
Baskets in which Sugar is exported from Java.* — Occasionally,
considerable quantities of sugar are brought from Java to the
American refineries packed in rough baskets or frails woven of
split cane, presumably a species of bamboo.   These baskets are
lined inwardly with palm leaves and they are strapped or tied with
flexible pieces of rattan.   They consist for the most part however
of the woven " cane " which is unlike and much larger than
rattan.   After they have been emptied, the baskets are washed
and steamed to remove any sugar which may have adhered to them
and they are then burned to ashes in the open air merely for the
sake of getting rid of them.   It is only occasionally that there are
any of the baskets to be burned, and as no value is attached to the
ashes they are commonly left lying exposed to the weather at the
place where they were formed.

The sample here in question was obtained in 1895 by my col-
league Mr. B. M. Watson from the Revere Sugar Refinery at East
Cambridge, Mass., and consisted of a moist, black mass which on
the addition of acids gave off some sulphuretted hydrogen.   For
the analysis, a couple of pounds of the material were ground to a
fine powder and thoroughly mixed.   It was noticed that this
powder was not very strongly alkaline.   In fact, 4.5105 grams
of the ashes neutralized no more than 0.01758 gram of sulphuric
acid (H_2SO_4).

A good general idea of the composition of the ashes may be got
from the following record of the analysis.   But it will be noticed
that the ferric oxide (and the other oxides) mentioned in the list

* Journal für Landwirthschaft.   1897, **45.** 80.

could not all have existed as such in the ashes which, as has been said, were more or less highly charged with sulphides and had evidently been subjected to reducing influences in the fire where the baskets were burned.

ASHES OF SUGAR BASKETS.

	As taken from the Yard.	Dried at 212° F.
Water	39.62	. .
Silica (and some Sand)	43.50	72.04
Charcoal	7.14	11.82
Ferric Oxide and Alumina	3.37	5.58
Lime	1.74	2.88
Magnesia	1.74	2.88
Phosphoric Acid	0.11	0.19
Potash	3.85	6.38
Soda	0.88	1.45
Chlorine	0.16	0.27
Carbonic Acid	0.52	0.87
Sulphuric Acid	traces.	
Sulphur	not determined.	

The small proportion of lime is noteworthy. The large amount of silica in the sample was naturally to be expected in any ashes obtained from bamboo or the like.

Even when regarded as perfectly dry, these ashes contain decidedly less of fertilizing matters than are found ordinarily in wood-ashes as obtained from house fires; and the fact that they are not to be had at all times, but only when the refineries happen to be occupied with Javan sugar, detracts not a little from their interest. And yet, though they are clearly inferior to wood-ashes, it may be said of them that they are well worthy the attention of farmers who are so situated that they could have the material from the refinery without much trouble or expense

I am indebted to my assistants, Messrs. W. W. Braman and J. M. Tilden and to Mr. A. W. Walker, a student at the Bussey Institution, for help in studying the subjects reported in the foregoing notes.

No. 37. — *On the Systematic Destruction of Woodchucks.*
By F. H. STORER, Professor of Agricultural Chemistry.

The common American marmot (*Arctomys monax*), known as
the Woodchuck in New England and as the Ground-hog in the
Middle States often does no small amount of mischief in vegetable
gardens and asparagus beds, and in fields of squashes, beans and
clover, while the burrows which he digs in hay fields are not a
little annoying, because of the liability that the knive-bar of the
mowing machine may strike the mound of gravel which has been
thrown out from the burrow and that horses may be injured by
stepping or breaking into the hole itself.

In spite of the incessant war waged against the animal by boys
and dogs and by the farmers with their guns and traps, it would
appear that the number of woodchucks in New England has in-
creased of late years, perhaps as a consequence of the decline of
the old style farming which occupied much land that is now practi-
cally abandoned. Several years ago I was led to consider the
question whether some methodical system of exterminating the
animal by chemical means might not readily be devised.

Vapor from Volatile Liquids. — The use of bi-sulphide of
carbon vapor, as practised successfully by Professor Hilgard in
California for the destruction of the ground squirrel of that locality,
seemed hardly to be applicable to large burrows which slant upward
in some part of their course, to say nothing of the danger of keep-
ing in store any considerable quantity of a volatile, highly inflam-
mable liquid. As a matter of course, bi-sulphide of carbon can
be obtained at small cost wherever there is any real demand for it
and it might perhaps be found to be an effective agent of destruc-
tion when used in sufficient quantity; though there can be little
doubt that a light petroleum naphtha would serve the purpose as
well and at less cost. In any event there would seem to be needed,
as regards the woodchuck, some device for forcing a considerable
quantity of the vapor into the very end of the burrow. Perhaps a
long tube connected with an æolipile blast lamp might answer the
purpose?

In case it should ever be found to be desirable to act upon Pro-
fessor Hilgard's idea of smothering the animals by the vapor of a
volatile liquid, a specially volatile kind of gasolene would naturally

take precedence of the bi-sulphide, at least here in the Atlantic States. Such naphtha might readily be prepared by the refiners of petroleum and could be supplied by them in any quantity at a nominal price. It is to be noted that while both these compounds are highly volatile, the vapors which they form are very heavy. These vapors are in fact much heavier than air and they would naturally tend to sink or flow downward towards the lowest point of any hole or burrow.

Poisons. — The idea of placing poisoned fruit or pieces of squash or some other vegetable in the burrows of the woodchuck is plainly inadmissible, because of the habit of the animal to bring up to the surface of the soil any edible matter which has been placed in his hole, presumably in order that he may find space to sit upon his haunches while eating. I have tested this matter carefully by pushing sweet apples down the holes of several woodchucks, in April, immediately after the animals had awakened from their winter's sleep. But in several instances I found afterwards half-eaten pieces of the apples lying upon the mounds of earth at the mouths of the holes into which they had been thrust. The marks of the woodchuck's teeth on the fragments of uneaten fruit thus brought up, left no doubt as to the habit now in question and showed how utterly inadmissible it would be to put poisoned fruit or vegetables in the holes, because of the risk that children or farm animals might subsequently find and eat some pieces of it.

Sulphur on Touch-Paper. — My attention was next turned to an old plan which is said to have been found useful for smoking out moles from their burrows, viz. the burning in the holes of sheets of touch-paper which have been saturated with Cayenne pepper, only that instead of the pepper I thought of using sulphur. After several trials of this idea, it became evident that pains would have to be taken to make the touch-paper highly inflammable and to add to it gunpowder or something such in order that heat enough should be generated to keep the excess of sulphur burning continuously. As a means of carrying out this plan, I sought to obtain some mealed-gunpowder from a neighboring pyrotechnist, Mr. B. M. Wedger of Roslindale, Mass., and was agreeably surprised to find that he had already worked out the idea of smothering woodchucks and had put it into practicable shape. On finding that he was prepared to supply " woodchuck torches " in any quantity at the modest

price of eight cents a piece, I immediately availed myself of this unexpected benefit and had no difficulty in materially diminishing the number of woodchucks on the estate which, at that time, I had in charge.

Mr. Wedger's "Torches." — In external appearance the wood-chuck torches resemble somewhat a Roman candle or a sky-rocket, *i. e.* they are stiff paper tubes, about 6 inches long and 1.75 inches thick, filled with a combustible mixture and carrying a short fuse at one end. At the time of my first acquaintance with Mr. Wedger he told me in confidence the composition of the mixture used for filling his torches. Since his death the establishment which he directed has been closed and I am permitted to publish the following receipt through the courtesy of his son, Mr. W. L. Wedger of Boston. It is to be presumed that — knowing the composition of the mixture to be put into the tubes — any maker of fireworks could prepare the torches.

Mr. Wedger's Receipt for Woodchuck Fire.

Nitrate of Soda	12 parts
Sulphur	6 "
Mealed-Gunpowder	4 "
Sulphide of Antimony	2 "

Both ends of the stiff tube in which the mixture is placed are packed firmly with clay, a hole being left in the middle of one of these plugs which serves not only for the insertion of the fuse, but is made large enough to allow of the suffocating fumes being discharged through it with great force. In using the torch, the fuse is lighted, the tube is thrust quickly into the woodchuck's burrow, a piece of board or a flat stone is placed upon the mouth of the hole and a quantity of earth is scraped over the board with a hoe, in order to prevent any of the smoke from escaping into the air.

The sulphide of antimony in the torch yields on burning a peculiarly dense and stifling smoke, and the combustion of the materials is so vigorous that the fumes are forced at once into every part of the burrow. It will be perceived that — as compared with other methods of smothering — an enormous advantage is gained from the *vis a tergo* of the burning torch, acting, as it must, to push the irrespirable vapor instantly to the innermost recesses of the hole.

Several of my friends, on testing the Wedger torch, have found, as I did, that it is a thoroughly effective means of destroying

woodchucks. At small expense, all the holes in a field may be fired with very little trouble. In our experience, it has been quite exceptional when one of the animals has ever shown himself again from a hole thus fumigated. In one locality indeed, where, from the character of the holes, or rather of the ground, an ordinary torch was found occasionally to be insufficient, one of my friends met the difficulty by having Mr. Wedger make for him some "double torches," twice as heavily charged as the ordinary. From the effects of these extremely powerful engines no wood-chuck has thus far escaped.

In order to prove beyond question that the smothering smoke of the torches does really suffocate the animals, my colleague, Mr. Edmund Hersey, having seen a woodchuck enter a hole in a sandy soil, put a sentinel on guard at the hole's mouth to prevent the animal from escaping, and hastened to his house for a torch. Subsequently, some little time after the torch had been fired, he had his men dig out the hole where they soon found the dead woodchuck.

This experiment of Mr. Hersey is not only interesting in itself, but is important as a verification of the fatal effect of the torch, for it is a fact that a woodchuck when once thoroughly alarmed will sometimes remain quietly in his hole for several days before he digs out and makes his escape. In some of my earlier experiments with inadequate mixtures of sulphur and touch-paper, I had repeated opportunity to observe this curious behavior which explains some extraordinary statements that have been published from time to time in the agricultural newspapers: — Such, for example, as that if a blank cartridge be fired from a gun into a burrow where a woodchuck is known to be and the hole is then closed with earth, the animal will never come out, but will either be smothered or frightened to death; or that in case a hole, known to contain a woodchuck, be plugged up with a wad of fusty old clothing — "smelling strongly of man" — the animal will never dare to dig out. It is true enough that in some cases a woodchuck thus treated might not pluck up courage to make his escape until long after the person who tried the experiment had become tired of watching for signs of deliverance.

It is to be observed, by the way, that the double torch above-mentioned might often be found useful as against foxes, not only

in agricultural practice, but by the custodians of parks and muni-
cipal reservations.   The ordinary torch may naturally be used to
destroy skunks as well as the woodchuck in cases where the burrow
is not too close to a combustible building.

Schemes for Using Sulphur. — Were it not for the danger of
transporting " fireworks " and of having them about the house,
there would be little incentive to try to improve upon the torches
above described, which could be prepared very cheaply if there
were a strong demand for them.   In so far as my own experience
is concerned, the use of them put so effective a check upon the
woodchucks within reach that it became difficult to continue the
experiments from mere lack of material.   I would have been glad
however to have tried one other plan, which would, practically,
have been to study the problem whether it be possible to burn, by
itself, enough sulphur in the limited volume of air in a woodchuck's
hole to smother an animal therein abiding.   The idea was to thrust
a hot Hessian crucible into the mouth of the burrow, to throw into
this crucible a lump of sulphur and to close the mouth of the hole.
Small crucibles, proper for the purpose, are obtainable from the
dealers in hardware, at the cost of but a few cents each.   Or, it
might be practicable to chip out a rough cup fit for the purpose
from a piece of fire brick.   It would be an easy matter to heat any
number of crucibles in a special fire — as of charcoal in a plumber's
fire-pot, or of gasolene in a plumber's blast-lamp — and to place
them in the holes by means of tongs.   The idea was simply to
have an earthenware vessel, unacted upon by sulphur and refrac-
tory to fire, which when once heated should remain hot long enough
to maintain the sulphur in combustion until the air in the burrow
has been used up and the oxygen of that air converted into sul-
phurous acid gas.

I find by experiment on throwing lumps of sulphur into Hessian
crucibles, which had been heated in a coal fire and set upon the
ground under kegs and barrels, that it would be important to find
out in actual practice how hot the crucible should be heated.   In
a crucible which has been heated hardly to visible redness sulphur
may remain melted and continue to burn slowly during half an
hour in a confined volume of air, but if the crucible were to be
heated red hot, any sulphur then thrown into it would distil off
rapidly, so rapidly indeed that in a confined volume of air much

of it would necessarily escape combustion and be volatilized as such, to be deposited again on the cool earth as flowers of sulphur. By the exercise of a little care the operator could readily guard against the risk of breathing any of the fumes from the burning sulphur.

Though sulphur used in this way would manifestly be less convenient than the torches and be intrinsically inferior to them, because of the absence of any force competent to push the sulphurous gas to the farthest extremity of the hole, it might perhaps be found to be possible so to control the burning sulphur that good results could be obtained with it. One difficulty might possibly be encountered in that an appreciable fraction of the sulphurous gas, when produced but slowly, might be absorbed by the soil. Actual trial would be necessary to determine whether the sulphur or the woodchuck would first be smothered. For it is not impossible that when most of the air in the hole had been used up, the hot sulphur might cease to burn before the vital spark of the animal went out. In point of fact, this result was actually arrived at on burning in the holes of woodchucks some of the so-called "sulphur candles," now to be had of the apothecaries for fumigating rooms which have been occupied by persons suffering from a contagious disease. It was found in repeated trials, that a large sulphur candle placed burning in a woodchuck hole ceased to burn long before the sulphur had been wholly consumed, and that the woodchucks dug their way out after waiting for several days.

A modification of the idea of burning sulphur in a warm crucible in the confined air of a burrow would be to try to blow in enough air to insure vigorous and rapid combustion. To this end a somewhat larger crucible might be used and a small tube be led from it to a pair of bellows, by means of which air enough might be forced in to generate, within the hole, a large quantity of sulphurous gas. Experience would determine how much time would be needed in this case, and, indeed, whether the method would be at all effective.

It is to be observed that an iron vessel would not be suitable for either of these experiments with sulphur, for a metallic vessel could hardly hold heat long enough to maintain the sulphur in slow combustion, and hot iron would be apt to combine chemically with sulphur and thus remove a good part of it from the field of usefulness.

Postscript. — Since the foregoing article was written, Mr. Henry Stewart has described a very effective method of destroying woodchucks. In the " Country Gentleman" for September 17, 1896, volume **61,** page 720, column 2, he says, " To get rid of ground hogs in grass fields, proceed as follows: Make cartridges of common blasting powder, or take one inch of a bar of dynamite, attach a fuse to the cartridge and push it down into the hole. Close up all others, and then the main hole with earth. Then light the fuse. If the animal does not come out head over heels with the earth, he will never come out at all after the explosion. This of course finishes up the whole colony, which may be a large one. One I have recently destroyed in this way had nine in the family, and there were exactly nine holes to the rather extensive burrow. Four ounces of common blasting powder did the business for the whole. The ground should not be blown out too much; the powder is to be gauged so as merely to lift the earth, which will settle down again without leaving a crater, while the gas will quickly suffocate the ground hogs."

No. 38. — *The Basket Willow.* By EDMUND HERSEY, Instructor in Agriculture at the Bussey Institution and Superintendent of the Bussey Farm.

Nearly half a century ago, on learning that a party in New York had imported from Europe cuttings of the European Basket Willow, I ordered several hundred cuttings for trial; for I had long been convinced that the introduction of any new tree, shrub, or vine that can be cultivated with profit, tends to improve the condition of the farmer, and to add wealth to the country.

The cuttings came to hand in good order on the 20th of April, 1853, and were set out in Hingham, Mass., in a soil of sandy loam, which had been prepared for a crop of potatoes. The slips were 12 inches long, and were set in rows 12 inches apart, and also 12 inches apart in the rows. Each cutting was set 9 inches below the surface of the ground, leaving 3 inches above, and on an angle of 45 degrees from the perpendicular; for many years of experience have proved to my own satisfaction that cuttings are more likely to live when set in this way than if set in a perpendicular position. Of the thousand cuttings set, every one lived and made a growth of from 3 to 6 feet the first season. No more time was spent in cultivation than would be required to cultivate a crop of potatoes. Since the crop of the first year was wanted for cuttings to set the following spring, it was gathered in November. Each shoot was cut into slips 12 inches in length, and they were all buried in a sand bank until the following April.

After the crop was harvested, the stumps from which it was cut were unprotected during the winter; they were found to be in good order in the following spring. During the summer the crop was neither fertilized nor cultivated, but was permitted to grow in its own free, natural, yet graceful way. When harvested in November, a measured rod of land produced 112 pounds of osiers, or within 80 pounds of nine tons to the acre; most of the osiers measured 5 to 6 feet in length, and some of them were within a few inches of 9 feet. A few of the osiers were sent to the editor of the New England Farmer, who in some remarks printed in 1855, vol. 7, page 85, concludes as follows: " We have specimens of his growth of willows now before us, very smooth and even, and about 9 feet in length."

Salix *viminalis* and Salix *purpurea* were the two varieties ordered from New York, but on investigation it was found that the importer, or his agent, had made a mistake, and had marked the purpurea, viminalis, and the viminalis, purpurea.   I am ignorant whether this mistake was confined to the cuttings sent to me, or whether it embraced all that were imported at that time. After several years trial with these two varieties, grown side by side, the variety bought for viminalis but proved to be purpurea, produced osiers so much superior to the other variety that all of the latter were destroyed, and only the purpurea plants were permitted to grow.

On my land the viminalis does not make so rapid growth as the purpurea, and it sends out more lateral branches; in fact with me it has proved a failure for both basket work and hoop-poles; but the *purpurea* has proved a great success, especially when grown on a soil of warm, sandy loam.   For more than twenty years a small area was kept covered with this variety, which without any cultivation or fertilizer, continued to produce every year good crops of osiers from 5 to 7 feet in length, which were sold to a party who cut and peeled them, and disposed of them to a party in Boston at a price of from 8 to 10 cents per pound; a higher price than the imported osiers sold for in Boston at that time. The party who bought the crop, paid for it what he thought it was worth, which was always more than could have been realized from any ordinary crop grown on the same area of land.

At the time of the death of the man who bought osiers of me, other business demanded my attention, and as the land was wanted for other purposes, most of my plantation of willows was destroyed, but enough were left to continue the experiment, to show that this variety of willows can be grown for many years on high, sandy land without cultivation or the application of fertilizers, and yet produce good osiers.   Forty-three years have passed since I began to grow these willows on the high land, and the yearly crops have never shown any signs of weakness.

Forty-five years ago, Mr. Lincoln Jacobs of Hingham, Mass., planted about one half of an acre of land with Salix purpurea; the soil selected was a rich, moist loam; a good soil for potatoes or grass; but it proved a very poor soil for the variety of willows he planted; many of the osiers were less than 4 feet in length,

and few of them more than 5 feet.   Mr. Jacobs, failing to get good osiers on rich, low land, planted a few on high, dry land, near his residence; and from this field he got osiers from 5 to 7 and even 8 feet in length every year, without applying any fertilizer or expending any labor in cultivation; this he continued to do as long as he lived, which was probably ten years after the cuttings were planted out.   Other parties planted the purpurea for hedges on high, dry land, but the growth was so rapid that it proved not suitable for hedges.

The question has arisen in my mind, why do most, if not all American writers who are considered good authority on the subject, recommend the viminalis and condemn the purpurea? and why is it that after forty-six years of trial, I find the purpurea an excellent variety for osiers, and the viminalis not worth growing?   Can it be that the soil of Hingham differs so much from that of any other part of the United States, that another variety of willows is required elsewhere to make a success in the business?   Can it be that so many writers have made a mistake in the variety of willows?   May it not be that the persistent efforts which have been made to grow the purpurea on wet land have led many to believe that this variety is of but little value, when if they had made the same efforts to grow it on dry land, they would have found it to be a variety of great value for osiers; if so, then it is time that this fact should be made known to the public; that those who are about to plant willows on high land may not make the mistake of planting varieties that are sure to make the business a failure.

So many associate the willow with running water, or low land, that it is very difficult to convince the public that there are varieties which grow best on sandy plains; yet years of close observation have proved to me that Salix *purpurea* not only grows best on dry land, but grows best in hot, dry weather.   By actual measurement it has been found that this variety in hot, dry weather with bright sunshine, will grow in a dry soil from 3 to 4 inches in twenty-four hours; while in rainy weather the growth does not exceed one half of an inch, though it be within a few days of the period when the growth was from 3 to 4 inches.

For more than forty years I have had a row of the purpurea willow growing on top of quite a high hill; about ten years ago,

a road was built on the south side of it, digging down some 4 or 5 feet, and quite a steep slope was made, the top of which was within a few feet of the willows; yet many of the osiers in this dry position have continued to grow as well as ever; during the past forty years, without cultivation, or the application of fertilizers, a yearly growth has been made of from 5 to 7 feet. I regret to say that road improvements require the removal of this row of trees the present year. Having kept them so long as a proof of their adaptability to dry land, I only submit to their destruction because it is important for me to do so.* During the forty-six years that the Salix *purpurea* has been grown by me, no injury has been caused to the roots or leaves by insects or fungi and it has proved to be one of the surest crops the farmer can grow, and also a profitable crop where the osiers are in demand for the manufacture of baskets and baby carriages, or for barrel hoops, nail keg hoops, or binders for boxes.

That the demand for osiers will rapidly increase, there can be but little doubt; and that most of them will be grown in this country is equally certain. From statistics published by the U. S. Government we learn that willow is quite rapidly taking the place of rattan. In the year 1880 the amount of willow manufactures in the United States was $1,992,851; in 1890 it was $3,633,592, or a gain of about 82 per cent. In the year 1880 the amount of rattan manufactures was $526,777; in 1890 it was $682,977, or a gain of less than 30 per cent. The amount of willow imported was as follows :

1858 . . . . $55,141		1880 . . . . $21,833
1865 28,028		1885 28,665
1870 50,115		1890 27,646
1875 34,440			

* Since writing the above, the road improvement has been made, and the willows removed. While digging the earth from under the willows, it was found that a tap-root the shape of a parsnip had grown from each of the cuttings set to establish the row of willows; these roots had no fibrous roots below the soil, and extended to an unknown depth; one was cut off 6 feet below the soil, and found to measure 4½ inches in diameter at the top, and 2 inches at the lower end. The soil under the willows was very much darker in color than that on either side, and from 3 to 4 inches deeper; it being 12 inches deep. Below the soil there was sand with loam enough mixed with it to slightly change the color, but not enough to hold the particles of sand together when pressed in the hand; under this sand was found a white sand free from stones, and fine enough to make good mortar; the depth of this sand is unknown, but pipes have been driven down 20 feet without reaching the bottom. Water would probably be reached at about 25 feet below the surface.

In selecting a soil best adapted to the growth of the Salix purpurea, a warm, sandy loam should be sought for; a soil that will produce good crops of Indian corn, is better adapted to the growth of this variety than a soil well adapted to the growth of grass.   To make the business of growing osiers profitable, a home market is needed; therefore if the business is to increase rapidly in this country, the manufacturers who use osiers should keep in close touch with the farmers, increasing their business as rapidly as the demand for their manufactures will warrant, and the farmers can be induced to furnish the osiers.

To prepare land that has not been under cultivation during the previous year, for a plantation of willows, a crop of Indian corn may be planted and several cords more of manure applied to each acre than the crop of corn will be likely to consume; the cultivation of the land should be thorough to prevent any weed seeds from ripening.   As early in the following spring as the land will work readily, it should be ploughed about 8 inches deep.   The slips for planting should have been cut from the stumps the previous autumn, a few weeks before winter sets in, and cut in lengths of about 12 inches, tied up in small bundles, and buried in a sand-bank, a few inches deep; if on the south side of the bank, it will be found when the slips are taken out in the spring, that the new roots have already begun to grow.   A few days after the land is ploughed, the cuttings should be planted; if the soil be fine and in good condition, the cuttings may be easily pushed into the ground about 9 inches, leaving 3 inches above the surface; it is best to set the slips on an angle of 45 degrees from the perpendicular; if set upright the roots at the lower end will be too deep to grow as rapidly as they would if nearer the surface, and the sap will not rise to the leaves as readily as on an angle.   The cuttings should be set in rows 2 feet apart each way.   In case the land be very weedy the first year, the weeds should be destroyed, but in doing so great care should be taken not to start any of the cuttings; for to disturb them before the roots get well started checks their growth if it does not kill them.   Experience has proved that cultivation is unnecessary on high land after the first year.

Unless the soil be very rich the crop should not be cut until it has made two years' growth, when if cut in the autumn and kept in a sandbank over winter it will make excellent slips for new

plantations, but of little value for osiers. When the crop is permitted to grow two years before cutting, the roots make a much more vigorous growth than they would have made if the shoots had been all cut off the first year. As the quality of the osiers depends on the size and vigor of the roots upon which they grow, it is not wise to adopt any practice which will check their growth or make them less vigorous. The roots being well established, the crop of the third year, will be valuable for osiers ; the shoots should be cut the following year a short time before the sap begins to flow, and if they are to be peeled without steaming, they should be tied in bundles of a convenient size with the osiers very even at the large end, that they may be set upright in water, about 3 inches in depth, where they should remain until the bark is in a condition to slip easily from the wood, when the work of stripping the bark from the osiers should begin and be continued, without interruption, until the work is completed. If the osiers are to be steamed to loosen the bark, the work may commence as soon as the osiers are cut, and when the bark has been stripped off the steamed osiers, they should be dropped immediately into a long trough of cold water, where they should lay a few hours, and then be taken out and dried in a storehouse where there is a good circulation of air. Dropping the osiers in cold water makes them dry a lighter color whether they are steamed, or peeled without steaming. When the osiers are well dried, they should be bound in bundles of from 30 to 50 pounds each, according to size and length, and sent to market.

When willows are to be grown to be used for the hoops of nail kegs or for the binders of boxes, shoots of nearly uniform thickness can be obtained by the device of stripping off, in the spring, all the lower leaves of those growing shoots which have already made one year's growth. In the spring, at the time when the leaves are about half an inch long, the top of the shoot is grasped in one hand, and all the leaves except a few at the top, are stripped off with the thumb and finger of the other hand. After a little practice this stripping can be done very rapidly; it prevents the growth of lateral branches, and secures the production of hoop-poles or box-binders which are entirely free from knots, and almost as large at the upper end as at the lower. A good two

years' growth is large enough for keg hoops or box binders; but for barrel hoops, three years' growth is not too large.

I have no doubt that a large and profitable industry could be built up in this country by growing osiers and manufacturing them into a great variety of useful articles, if the farmers could be induced to get the best varieties of willows for osiers, and to plant them on a soil best adapted to their growth. But because of the "information" which has thus far reached the farmers, it would probably happen in case osier cuttings were given to 100 of them, that 99 would set out their cuttings on a bank beside a stream, or on some low land of but little value for any purpose. There is in this country a belief so firmly established in the minds of all classes, that the home of the willow is by the side of running water that it will probably not be easy to convince any considerable number of persons that there is any variety of willow producing excellent osiers, which grows better on sandy loam than on moist, loamy soil. To establish this truth, and to do away with the erroneous prejudice now current, both precept and example will be needed in full measure.

I cannot but hope that my own success during forty-six years of experiment and observation, may invite others to make such investigations as may be necessary to ascertain what soil is best adapted to the growth of each variety of willow used for manufacturing purposes.

The question will arise naturally, where did my willows obtain food enough to produce vigorous growth each year for forty years in succession, while during the same time it was evident to the eye that the character of the soil in which the fibrous roots grew was improved?

It is quite probable that the large tap roots of the willows reached down to an abundant supply of water containing the mineral elements required for plant growth, in sufficient quantities to furnish a full supply for the rapid growth of the osiers. A portion of the mineral elements may have been obtained by the disintegration of the soil, hastened by the action of acids given off from the willow roots. The deepening and enrichment of the soil was evidently caused by the yearly dropping of the leaves which were kept from being scattered over a wide space by the numerous stumps from which the osiers were yearly cut.

I am led to the above conclusions by the fact that some years ago, for the purpose of keeping some willow cuttings over winter, I buried them in a bare sand bank from which all the original soil had been removed. By accident, a few of the cuttings were left in the sand where they sprouted and grew rapidly. After the second year, they grew from five to seven feet each year for more than twenty years without the application of any fertilizer, and without cultivation. During the past ten years, these willows have been permitted to grow without being cut; on examination I find that the sand beneath them is covered with a good soil.

On submitting some of the fibrous willow roots to my colleague, Mr. E. W. Morse, for microscopic examination, he finds that while there are root-hairs upon some of the roots others are devoid of hairs and that the hairless roots are enveloped by fungus threads. It is to be inferred, therefore, from what is known of the power of fungi on the roots of forest trees to take nitrogen from the air, that a part at least of the nitrogenous food of my willows has been derived from the air — a conclusion which is consistent with the rapidity of their growth upon land which was naturally by no means fertile.

No. 39. — *On the results of a Search for other Sugars than Xylose and Dextrose in the products of the Hydrolysis of Wood from the Trunks of Trees.*   By F. H. STORER, Professor of Agricultural Chemistry.

Several years ago I had occasion * to call attention to the fact that not infrequently undue prominence has been given to the opinion somewhat widely held by botanists, and by chemists also, that an abundance of starch is stored in winter as a " reserve matter " in the wood of many kinds of trees.   In reality, there is much less starch in the trunk-wood of trees growing in temperate or northern climates than has ordinarily been supposed.   Hence the need of studying anew the general question, What are the reserve matters in trees?   As well as the specific question, Whence comes the sugar which is found in the spring in the sap of many kinds of trees?

It is to be remarked that the false impression as to the presence of much starch in woods depended primarily on the use of improper methods of analysis for estimating the starch ; † though it is not improbable that too much importance may sometimes have been accorded to the microscopical observations of botanists on the presence of starch in the twigs of trees.   In so far as the life of the whole tree is concerned, it may perhaps be true that the reserve starch stored in twigs should be regarded in some sort as a matter of merely local significance.

It is true of course that the wood of the trunks of trees often or even usually contains in store some starch and that in the bark also there can be found small quantities of sugars and of substances, such as glucosids, which may be capable of reducing cupric oxide after they have been subjected to the action of water, diastase and a dilute acid, as happens in the process of analysis which depends on the application of malt.   But inasmuch as the visible effect produced by matters held in store in trees is often out of all proportion greater than can be credited to the small quantities of starch and glucosids exhibited by analysis, it seems probable that there must be other carbohydrates stored habitually

* Bulletin of the Bussey Institution.   1897, **2.** 386.
† Loc. cit., page 391.

in trees as reserve matters and that some of them are equally important with starch, or possibly more important, as a means of carrying forward the life of the tree from one year to another.

It has been suggested not infrequently that the cellulose or, better yet, some of the hemicelluloses in plants should be regarded as capable of supplying matters for the sustenance of the plant, and this idea is supported by the fact that cellulose yields dextrose when subjected to the action of strong acids, and that several observers have noticed that it is often acted upon by enzyms of one kind or another.*

It would be a matter of no little interest to determine what other substances (if any) beside cellulose that are capable of yielding sugars by hydrolysis could be detected in woods, and the motive of the research here described was to ascertain if possible whether any suggestions as to the presence in woods of substances hitherto undetected could be got by testing roughly though methodically the reducing power and the rotatory power of various products obtained by hydrolyzing woods with acids.

It was found by preliminary trials that after xylan had been removed (in some part) by boiling the powdered woods in dilute acids, it is easy to obtain no inconsiderable quantities of sugar by treating the residual wood with strong acids and subsequently diluting and boiling the mixture. On neutralizing and decoloriz-ing (if need were) these solutions, after the hydrolysis, they were tested quantitatively for sugar, by means of Fehling's liquor, and their rotatory power was observed with a Schmidt and Haensch polariscope.

Inasmuch as the solutions necessarily contained, beside sugar, extractive matters of one kind or another, it would have been impracticable to determine the specific rotation in each case by the usual and conventional method; for, in order to do that, we need to know the quantity of sugar that is contained in a deter-mined weight of the solution, while in the method here employed we can find only the quantity of sugar in a measured *volume* of the solution. But it is still possible to compare these determina-tions one with another, and to obtain an approximation to the true specific rotation by making use of the formula

* Green, J. R. ,The Soluble Ferments and Fermentation, Cambridge, 1899, pp. 84–103.

$$(a)\ D = \frac{a \times s}{l \times g}\ \text{in which}$$

$a =$ the observed angle;

$l =$ the length of tube;

$g =$ the number of grm. of dextrose in s, as determined by Fehling's liquor;

$s =$ the number of c.c. of the saccharine solution taken.

I have designated these approximate rotations as "quasi-$(a)\ D$," and it is to be observed that the results set forth in this article have all been obtained in this way, unless otherwise expressly stated.

It should be observed that although the figures of the quasi-rotations are always somewhat higher than those of the true specific rotations, they must nevertheless depend upon definite relations which subsist between the quantities of sugar detected in the solutions and the angles of rotation actual y observed in the polariscope.

For the sake of illustration a sample of pure dextrose was tested in the manner and by the formula above stated, and there was obtained as the approximate specific rotation of this substance, quasi$(a)\ D = 56°.84$; while pure galactose (from Merck & Co.) treated in the same way gave quasi$(a)\ D = 86°$.

Whereas, the true specific rotations $(a)\ D = 53°.40$ (for dextrose) and $(a)\ D = 79°.94$ (galactose) were obtained on testing these very samples in the conventional way and calculating from the observed data by means of the proper formula, viz.

$$(a)\ D = \frac{a\,(p + q) \times 1.00125}{p \times d \times l}\ \text{in which}$$

$a =$ the observed angle;

$p =$ the number of grm. of sugar;

$q =$ the number of grm. of water;

$l =$ length of the tube;

$d =$ sp. gr. of the solution at $17°.5$;

$1.00125 =$ factor for reducing the sp. gr. to $4°$ C.

In the preliminary trials above mentioned, it appeared as a rule that the rotatory power exhibited by the products of hydrolysis was appreciably higher than could have been the case if only dextrose had been present. Thus, several specimens of maple wood, hydrolyzed as above described, after the action of strong acid and tested in the manner indicated gave the results which here follow: quasi$(a)\ D = 63°,\ 65°,\ 66°,\ 68°,\ 69°$ and $73°.5$, re-

spectively. Birch wood similarly treated gave quasi(a) $D = 64°.5$; and pine wood gave quasi(a) $D = 71°$.

It was with the hope of explaining this matter that systematic experiments upon maple and birch woods, and upon cotton cloth also, were made, as is described on the following pages : —

A. *An Examination of the products of the Acid Hydrolysis of Wood from the trunk of a Sugar Maple Tree (Acer saccharinum).* — Ten grams of maple wood in fine powder taken from the outer part (wholly free from bark) of the trunk of a tree four inches in diameter, felled on May 30th, in West Newfield, Maine, were soaked during 24 hours in 200 c.c. of strong ammonia-water, to remove coloring matter and albuminoids, and were then thrown upon a filter and washed with water. Enough dilute hydrochloric acid, of 3%, was poured into the filter to displace the moisture retained by the wood, and the latter was then boiled in a flask, with reflux condenser, over a free flame, with 200 c.c. of hydrochloric acid of 3% during 3.5 hours. The undissolved wood was removed by filtration, and one half the product of the hydrolysis was neutralized with sodium hydroxide and decolorized with bone-black. On testing the solution with Fehling's liquor it appeared that 100 c.c. of it reduced as much cupric oxide as would have been reduced if the solution had contained 0.5669 grm. of dextrose. This quantity would be equal to 16.21% of dextrose in the dry wood. On observing in the polariscope through a 2 dm. tube a rotation of $0.5°$ was noted, *i. e.* quasi(a) $D = 44°.09$.

The other half of the liquid that had been removed from the wood was boiled 3.5 hours longer over a free flame, and was then neutralized and decolorized as before. The specific rotation in this case was quasi(a) $D = 68°.17$, and Fehling's liquor showed "sugar" (calculated as dextrose) equal to 10.43% of the dry wood.

Due allowance being made for the possibility of the presence in the solution of matters other than sugars, which might have some influence on the rotatory power, it is to be presumed that the sugar observed in the product of the first hydrolysis probably consisted of a mixture of xylose and dextrose, and that some of the latter was made to "revert" to compounds of higher rotatory and lower reducing powers by the second boiling, after the removal

of the wood. Such reversion has repeatedly been noticed by chemists,* and there are researches by Grimaux and Lefèvre,† by Gautier,‡ and by Fischer,§ which help to explain what kinds of products are formed.

The residual wood, taken from the acid liquor of these first trials with dilute acid, was soaked in strong hydrochloric acid of 35%, during 24 hours, and the mixture was then poured into boiling water, taken in such quantity that the final strength of the acid in the mixture should be 3%. In the 3% acid thus obtained, the residual wood was boiled over a free flame during 6 hours. The liquid was then neutralized with sodium hydroxide, evaporated, and decolorized with bone-black. The specific rotation was found to be quasi $(a) D = 70°.84$, and Fehling's liquor showed 3.79% of "dextrose" calculated on the material operated upon or to 3.17% of the dry wood.

The wood left after the foregoing treatments with hydrochloric acid was rubbed up with 10 c.c. of concentrated sulphuric acid (of 92.5% H_2SO_4), and the dark brown mixture was left to itself during 24 hours; it was then poured into enough boiling water to yield an acid containing 3% of H_2SO_4 and was boiled therein during 3.5 hours. After filtration a part of the liquid was neutralized with sodium hydroxide. It was clear enough to be examined without the use of decolorizing agents. It gave quasi $(a) D = 66°.16$ and "dextrose" amounting to 33.50% of the dry residue or to 27.04% of the dry wood. This solution may be called "A." Another portion of the filtered acid liquid was boiled 3.5 hours longer, without any further addition of acid, and was then neutralized with calcium carbonate, filtered and evaporated. The solution was clear enough to be examined without decolorizing it. The approximate specific rotation was quasi $(a) D = 64°.82$, and the "sugar," as shown by Fehling's liquor and calculated as dextrose, amounted to 35.08% of the dry residue. This solution may be called "B."

* Compare, for example, the memoir of Wohl in Berichte der deutschen chemischen Gesellschaft. 1890, **23**. 2095, and Wohl's list (on p. 2084) of the names of chemists who have worked upon the subject.

† Comptes Rendus. 1886, **103**. 146.

‡ Bulletin de la Société Chimique de Paris. 1874, **22**. 145.

§ Berichte der deutschen chemischen Gesellschaft, **23**. 3687, **26**. 2400, **27**. 2478, **28**. 1145, 1167, 3024.

The high rotatory power exhibited by these products of the hydrolysis of wood, taken in connection with other results of similar import which had been obtained previously while studying other specimens of woods, pointed most distinctly to the presence of some other reducing substance beside dextrose and xylose; for the true specific rotation of xylose * is $(a) D = 19°.2$ and that of dextrose * is $(a) D = 52°.6$. Efforts were made at once to isolate this additional substance. To this end a part of each of the sulphuric acid solutions "A" and "B" were allowed, after neutralization, to evaporate spontaneously (in mid-winter) at the ordinary temperature of the laboratory. From "A" crystals of sodium sulphate separated and were removed. The brown residues from the evaporation were rubbed up with three successive portions of strong alcohol. A part of the matter dissolved while there was left a sticky, stringy dextrin-like mass insoluble in strong alcohol, though readily soluble in cold water. The aqueous solution of this substance had a flattish, sweetish taste, as was noticed in other instances. That from "A" gave quasi $(a) D = 89°.69$. Meanwhile, the matter soluble in alcohol, obtained from "A," was taken up with water after the alcohol had been driven off, and this solution gave quasi$(a) D = 66°.18$, calculated as dextrose, as was the preceding.

From the solution "B," which was boiled in the dilute acid longer than "A" had been boiled, a somewhat different result was obtained. The matter left undissolved by strong alcohol in this case was not wholly soluble in water. The insoluble residue was granular rather than gummy, and the solution obtained by means of water had practically no reducing action on Fehling's liquor.

The matter soluble in alcohol in this case gave quasi$(a) D = 69°.57$, when examined in aqueous solution and calculated as dextrose. It is evident from the foregoing that that product of the hydrolysis which fails to dissolve in strong alcohol (as in "A") is apt to suffer decomposition when boiled for a long time in dilute acids. It will be noticed that in all these experiments no wood was left in contact with the acid during the second boilings; the acid then had nothing to act upon but the products formed by the first boiling. The nature of this decomposable substance will be discussed in subsequent paragraphs.

* Tollens, Handbuch der Kohlenhydrate. 1895, **2.** 5.

B. *Acid Hydrolysis of Wood from the Root of a Sugar Maple Tree.* — A root, from an inch to an inch and a half in thickness, was dug up in November at West Newfield, Maine.   The bark was stripped off and the wood ground to powder.   A quantity of the powdered wood was soaked in strong ammonia water during 24 hours, and then thrown upon a filter and washed with water. The wood thus leached with ammonia was dried at 100° and subjected to hydrolysis as follows : Seven grams of the dry residue were boiled for three hours in 200 c.c. of hydrochloric acid of 3%, and the undissolved residue was separated by filtration. One half of the liquid was neutralized with sodium hydroxide, evaporated, and decolorized with bone-black.   It gave quasi (a) $D = 59°.26$, and there was shown by Fehling's liquor 23.04% of "sugar" (calculated as dextrose) in the dry root wood that had been leached with ammonia.

The other half of the acid filtrate was boiled three hours longer, and then neutralized with sodium hydroxide and decolorized with bone-black.   The approximate specific rotation in this case was quasi(a) $D = 68°.21$, and the "dextrose" shown by Fehling's liquor was equal to 16.30% of the dry wood that had been leached with ammonia.

Both the higher rotation observed in these two trials of root wood and the larger percentage of dextrose, as compared with the corresponding experiments with trunk wood, are explained by the fact that the wood of the maple root contained much more starch than the trunk wood did.   While the latter was well nigh absolutely devoid of starch, the root wood when tested with barley malt showed as much as from 5 to 7% of "starch and sugar," *i. e.* matters capable of reducing copper from Fehling's liquor. Indeed, on merely boiling some of the powdered root with successive portions of water, enough reducing matter was dissolved to indicate 4.12% of sugar ("dextrose") when tested with Fehling's liquor, while the trunk wood gave no indication of starch when thus tested.   Under the microscope also much more starch was found in the root wood than in the trunk wood.*   All of which

* My colleague, Mr. E. W. Morse, who was good enough to examine the specimens, noticed much blue coloration on testing the maple root wood with iodine, although he obtained no reaction for starch, either in the outer or inner wood or in the bark of the trunk of a maple tree that had been felled

consists with the view, not infrequently enunciated, that appreciable quantities of starch are stored in the winter in the roots of trees.

As was the case in the experiment described on page 440, so here, the long continued boiling appeared to have produced reversion (or destruction?) of a part of the dextrose that had been formed at first. On mixing what remained of the two solutions from the hydrolysis with 3% hydrochloric acid, they were evaporated nearly to dryness and the residue was treated with strong alcohol. The matter insoluble in alcohol gave quasi $(a) D = 84°.69$, and the matter soluble in alcohol gave quasi $(a) D = 39°.41$.

The residual wood left after hydrolyzing with hydrochloric acid of 3% was soaked in 80 c.c. of strong hydrochloric acid of 35% during 24 hours in the cold, and the mixture was poured into enough boiling water to dilute the acid to a strength of 3%. The diluted mixture was boiled during three hours and then filtered. One half the filtrate, neutralized with sodium hydroxide, evaporated, and decolorized with bone-black gave quasi $(a) D = 76°.78$ and "dextrose" to the amount of 7.33% of the dry material operated upon, or to 5.64% of the dry wood that had been leached with ammonia.

The other half of the acid filtrate, after having been boiled three hours longer, gave anomalous results, as to rotatory power, while Fehling's liquor showed only 2.94% of "dextrose" calcu-

on May 1st. A hardly visible reaction with iodine was got, along the medullary rays, on testing the outer and inner wood of a maple tree felled on May 30th. On examining wood and bark from the trunk of a sugar maple tree, felled in October, he got no reaction for starch in the bark; and the outer wood gave the starch reaction only in the medullary rays, excepting a few cases where scattering starch grains were detected in the wood fibre, usually not far from the medullary rays. Some starch grains were observed in the medullary rays of the inner wood also, but they were few in number, *i. e.* they were still less numerous than those observed in the outer wood of the same tree.

Pith from a stem of an elder bush (*Sambucus*) cut in July gave no reaction with iodine. Wood cut from the stem of a red maple tree in June gave a decided reaction along the medullary rays, while wood cut on the same day from a gray birch tree showed only a slight coloration with iodine; indeed, there were so few of the blue colored granules lying in the medullary rays that they could readily be counted.

lated on the dry wood that had been leached with ammonia. To all appearance much of the sugar produced in the first hydrolysis had been destroyed by the second boiling.

The residual wood, from the foregoing hydrolysis with strong hydrochloric acid, was treated with 10 c.c. of concentrated sulphuric acid (of 92.5% H_2SO_4) and left to stand in the cold during 24 hours. It was then poured into enough boiling water to bring the mixture to a strength of 3% H_2SO_4, and the whole was boiled for three hours. The filtered liquid was divided into two parts. One part was neutralized with calcium carbonate and evaporated. It did not need to be decolorized. The solution gave quasi$(a)D = 73°.48$ and "sugar" enough to amount to 32.12% of dextrose in the dry matter operated upon, or to 22.91% in the dry wood that had been leached with ammonia.

The rest of the neutralized solution was evaporated to dryness and the residue was treated with hot, strong alcohol. The light brown, sticky mass insoluble in alcohol did not need to be decolorized when taken up with water. It gave quasi$(a)D = 79°.34$, and Fehling's liquor indicated 19.29% of sugar calculated as dextrose on the dry wood that had been leached with ammonia.

The matter soluble in alcohol, on being dissolved in water, after the expulsion of the alcohol, gave quasi$(a)D = 54°.60$, and Fehling's liquor showed dextrose enough to amount to 13.93% of the dry wood that had been leached with ammonia.

The second portion of the acid filtrate from the hydrolysis with 3% sulphuric acid (after the action of strong sulphuric acid) was boiled three hours longer, after it had been removed from the wood. It was then neutralized with calcium carbonate and evaporated. The solution did not need to be decolorized. It gave quasi$(a)D = 68°.58$, and Fehling's liquor showed 33.16% of "dextrose" calculated on the dry substance operated upon. On being again evaporated, it was treated with hot, strong alcohol. The matter insoluble in alcohol on being dissolved in water gave quasi$(a)D = 58°.33$, and Fehling's liquor showed 22.92% of "dextrose." The matter soluble in alcohol gave quasi $(a)D = 66°.30$, and Fehling's liquor showed 9.45% of dextrose.

It will be noticed that, as indicated by Fehling's test, the total amount of sugar obtained from the three prime hydrolyses of the maple root was by no means inconsiderable. After the first

action of the 3% hydrochloric acid on the wood that had been leached with ammonia the tests indicated 23.04% of sugar; after the second action (3% HCl, after soaking in strong, cold HCl) the tests showed 5.64%, and after the treatment with strong sulphuric acid they showed 23%. That is to say, the indications were that nearly 52% of sugar, all told, had been got from the root wood which had been leached with ammonia and dried at 100°.

In the case of the trunk wood the tests showed, respectively, 16.21%, 3.17% and 27.04% of " dextrose." In all 46.42% of the dry wood. These figures (as indicated by Fehling's liquor) depend of course solely on the presumption that the observed reductions were due to the presence of sugars properly so-called. As will be shown directly this presumption is not justifiable; but at this stage of the investigation it was regarded as a not wholly improbable hypothesis, and many efforts were made to isolate in visible, tangible form the substance whatever it might be that exhibited a higher rotatory power than dextrose. For example, rather more than 50 grm. of powdered maple root were boiled over a free flame in a flask with reflux condenser for three hours with 1000 c.c. of dilute sulphuric acid (of 3.5%) to remove starch and some of the xylan. The filtrate obtained in this way was neutralized with calcium carbonate, evaporated and examined. It showed quasi(a) $D = 47°.87$ and "dextrose" (in some part xylose) enough to amount to 14.35% of the dry wood.

The undissolved residue from this first treatment was left over night to dry out somewhat in the air and 30 c.c. of strong sulphuric acid, of 90% H_2SO_4, were added to it. The mixture was left to itself during 24 hours, and was then poured into enough boiling water to reduce the acid to the strength of 3.5%. After this dilution the mixture was boiled over a free flame for 3 hours, and the filtrate was set aside to be added to the product of the next hydrolysis.

In this particular instance the treatment with strong sulphuric acid was not wholly satisfactory, because in the course of it evidence presented itself that the residue from the treatment with 3.5% acid had not been adequately dried. It had, in fact, retained so much moisture that the strong acid added to it was at once diluted to such an extent that it had no proper opportunity

to act upon the cellulose in the wood. It was noticed, for example, that even 30 c.c. of the strong acid made a pasty mass with the residue, and that only a small part of the residue was blackened. Hence, the residue from this treatment with strong acid was dried carefully and again mixed with a new portion of the strong sulphuric acid. In this case the residue blackened instantly and throughout when the strong acid was added to it, and 70 c.c. of the acid were required to bring about the desired pasty condition.

After standing during 24 hours the mixture was poured into enough boiling water to reduce the acid to the strength of 3.5% and boiled over a free flame for 3 hours. The filtrate from this treatment was added to that previously obtained, as above stated, after the first application of the strong acid, calcium carbonate was added to neutralize the acidity and the filtered liquid was evaporated to a syrupy condition. After decolorizing with bone-black, this solution showed quasi$(a)D = 63°.42$ and "sugar" enough to amount to 9.65% of the dry wood.

It is worthy of remark that in this trial where 50 grm. of wood were boiled directly in an acid of 3.5% and the residue was treated with sulphuric acid of 90% H_2SO_4, and where a 3.5% acid was used again in the final hydrolysis, less sugar $(14.35 + 9.65 = 24\%)$ was obtained than had been got previously where a smaller quantity of wood (10 grm.), a slightly weaker dilute acid (3%) and a more concentrated strong acid (92.5% H_2SO_4) were employed; for in that case the yield of "sugar" was $23.04 + 5.64 + 23 =$ nearly 52%. So, too, in subsequent trials, less sugar was got from 50 grm. portions of wood after treatment with acid of 90% than had been got in the earlier trials.

In respect to the action of strong sulphuric acid, it may here be said that (after the wood had soaked in strong acid) the 10 gram portions were boiled in 464 c.c. of acid of 3.5%, while the 50 gram portions were boiled in 3250 c.c. of acid of 3%.

Another difference of treatment in the two particular instances above cited was that the 10 gram portion had been leached first of all with ammonia, then boiled with dilute hydrochloric acid and afterwards soaked in strong hydrochloric acid, and again boiled in this acid, after dilution, before they were soaked in strong sulphuric acid; while neither ammonia nor hydrochloric

acid were used upon the 50 gram portions of wood. Here the powdered wood was boiled at once in dilute sulphuric acid of 3.5%, and afterwards soaked in the strong sulphuric acid of 90%, and again boiled, after dilution to 3.5%.

In the hope of obtaining crystals 15 grm. of the thick syrup, left on evaporating the neutralized liquor from the hydrolysis by dilute acid after treatment with strong sulphuric acid, were warmed in a dish together with 10 c.c. of water, and 20 c.c. of strong alcohol were added. After three days it was found that a slimy mass had settled at the bottom of the dish. Sixty c.c. of strong alcohol were poured upon it, and the dish was left to itself in an exsiccator. No perceptible change occurred in the course of a fortnight; the clear brown solution was then filtered off and the stringy brown residue was washed with a little dilute alcohol. It became white under this treatment. On attempting to dry it on a watch-glass in an air-bath, it began to melt at 70°; when it was immediately taken from the bath and set aside in an exsiccator. Next morning the contents of the watch-glass were found to be solid, and numerous needle-like crystals were visible upon and in the midst of the mass. Under the microscope the crystals were well defined, and it could be seen that many of them had pyramidal terminations. After a time these crystals effloresced in dry air. The whole of the crystalline mass was tested for mucic acid by treating it with nitric acid of 1.15 sp. gr. It was oxidized completely by this acid, and a clear solution was obtained from which after a while a white powder was deposited. This precipitate was so white and of such excellent appearance that the treatment with ammonium carbonate, ordinarily employed for separating mucic acid from insoluble contaminations, was omitted and the precipitate was collected directly and weighed. Dried at 100° it amounted to 11.36% of the weight of the crystalline mass, supposed to contain sugar, which had been subjected to the action of the nitric acid; on examination, however, the precipitate turned out to be not mucic acid but mere inorganic matter. On dissolving it in ammonium carbonate, evaporating to dryness and treating anew with nitric acid, only a very small precipitate appeared, and this also was found to consist wholly of inorganic matter, the source of which will be suggested on page 464.

In order to determine whether the matter insoluble in alcohol, obtained as above, is always contaminated with inorganic substances, another portion of the powdered maple root (more than 50 grm.) was hydrolyzed as before; first with dilute sulphuric acid of 3.5%, to remove starch and xylan, and subsequently after treatment with strong sulphuric acid of 90% H_2SO_4, with acid that had been diluted to 3.5%. In the treatment of this sample care was taken to dry thoroughly the residual cellulose left after the action of the first acid of 3.5%, before adding to it 70 c.c. of strong sulphuric acid. This strong acid was left in contact with the cellulose during 24 hours, and was then diluted to 3.5% and boiled and examined as before.

In this instance the liquor obtained from the first hydrolysis with 3.5% acid, and supposed to contain a mixture of xylose and dextrose, showed quasi $(a) D = 42°.87$ and enough "sugar" to amount to 15.48% dextrose, calculated on the dry wood. On the other hand, the product of the hydrolysis after the action of strong sulphuric acid gave quasi $(a) D = 63°.75$ and "sugar" enough to amount to 1.07% of the dry wood.

The syrup left on evaporating most of the liquor from the hydrolysis after the strong acid was a brown molasses. Strong alcohol was added to it in three successive portions, the last portion being left over night in contact with the insoluble matter. This precipitate, which was lighter colored than the syrup from which it came, was dissolved in a very small quantity of water and heated carefully upon an oil bath to 65° C., and then set aside in a dessicator to cool. After 24 hours the dish was found to contain a solid crystalline mass in and upon which, as in the previous instance, were to be seen numerous acicular crystals. Under the microscope these needles seemed to be hexagonal prisms, many of which had well defined terminations. After a day or two these crystals effloresced in dry air, while preserving their original shape. They were found to consist for the most part of inorganic matter.

The solution obtained on dissolving this crystalline mass in water showed no disposition to form a syrup on being evaporated. On the contrary, it left a dark-brown, somewhat granular residue which remained unchanged in appearance on the addition of strong alcohol. After driving off the alcohol, dissolving in water,

decolorizing with bone-black, and again evaporating to dryness, a very small quantity of water was added, the mixture was heated to 60° and set aside in an exsiccator; it dried out to a solid mass in which no crystals were visible. Six weeks later, on treating the dry residue with alcohol of 75%, a very small portion of it dissolved; but most of it dissolved in alcohol of 60%. The alcohol solutions, mixed one with the other, showed no indications of crystallizing, but dried down to an amorphous mass which was taken up with four fifths its weight of water. On adding to this solution twice its volume of alcohol of 93%, an apparently gelatinous precipitate began to form and increased on standing. This precipitate was found to consist of fine crystals of inorganic matter. Moreover, the residue which was left undissolved at the time of treating with alcohol of 60% was seen to consist of white crystals of inorganic matter.

For the moment it was a matter of uncertainty whether this inorganic matter consisted merely of ash-ingredients proper to the wood, or whether it might not have been derived from acids, produced in the process of hydrolysis, that were capable of forming soluble calcium salts. In the hope of avoiding the inorganic substances which had thus far contaminated the " matter insoluble in alcohol," various experiments were now made with carbonic acid; and with lead carbonate as the neutralizing agent, instead of calcium carbonate or barium hydroxide, and with cotton also instead of wood. For the conclusions to be drawn from the results of these trials, see page 463.

The unusually small quantity of sugar (1.07%) obtained in the experiment, described on page 449, led to a repetition of it.

Some 54 grm. of powdered maple root were boiled for 3 hours in 1000 c.c. of dilute sulphuric acid of 3.5%, to get rid of xylan and starch; the residue was dried in the air and treated with 70 c.c. of strong sulphuric acid of 90% H_2SO_4, then poured into 3247 c.c. of boiling water to reduce the acid to a strength of 3.5% and boiled for 3 hours. The filtrate was neutralized with calcium carbonate, and, after the precipitated calcium sulphate had been removed by filtration, carbonic acid gas was passed into the clear liquor which was subsequently boiled. The slight precipitate which formed was filtered off, and the liquid was evaporated to the bulk of 428 c.c. It did not need to be decolorized.

It gave quasi$(a) D = 79°.89$ and 13.61% dextrose calculated on the dry root wood. On being evaporated to dryness and treated with strong alcohol, a large portion of the residue failed to dissolve.

In still another experiment rather more than 50 grm. of powdered maple root were boiled for 3 hours in 1000 c.c. of 3.5% sulphuric acid; the undissolved wood was filtered off, dried thoroughly, and left to soak during 24 hours with 70 c.c. of sulphuric acid of 90% H_2SO_4. The mixture was poured into 3250 c.c. of boiling water, and the boiling was continued during 3 hours. The filtrate was neutralized with lead carbonate, and, after the removal of the lead sulphate, sulphuretted hydrogen was passed through the filtrate to remove any lead which might be held in solution. After removing the lead sulphide and the excess of sulphuretted hydrogen, the solution tested with Fehling's liquor showed 0.84% of dextrose, calculated on the dry wood, and gave quasi $(a) D = 82°.15$. The low percentage of dextrose is remarkable.

C. *Acid Hydrolysis of Wood from the trunk of a Birch Tree* (*Betula populifolia of Aiton*). —The wood submitted to examination was the outer part of the trunk of a gray birch tree four inches in diameter that had been felled in the month of October. After the outer and inner bark had been removed, that portion of the outer wood which lay between the bark and a circle drawn half an inch inward from the bark was split off and ground to a fine powder. Ten grams of this powder were soaked in 200 c.c. of strong ammonia water for 24 hours to remove coloring matters and albuminoids, and the excess of ammonia was removed by washing. The wood was then mixed with 200 c.c. of hydrochloric acid of 3% and boiled for three hours, over a free flame, in a flask provided with a reflux condenser. One half of the filtrate from the wood thus treated was neutralized with sodium hydroxide, evaporated, decolorized with bone-black, and tested. It gave quasi$(a) D = 62°.85$ and 19.8% of "sugar" calculated as dextrose on the wood dried at $100°$ C.

On evaporating the solution to dryness and treating the dry mass with cold, strong alcohol, there was obtained a residue which gave quasi$(a) D = 76°.81$, while the portion soluble in alcohol gave quasi$(a) D = 24°.52$; both observations being made,

of course, upon aqueous solutions after the alcohol had been driven off, — the references are to dextrose. It is evident that the matter insoluble in alcohol contains some substance of higher rotatory power than dextrose, while as regards the portion soluble in alcohol it is to be inferred that it contained much xylose, the true specific rotation of which is $(a)D = 19°.2$. Calculated as dextrose, the matter insoluble in alcohol amounted to 4.65% of the dry birch wood, and the sugar soluble in alcohol to 12.54%.

The second half of the filtrate, from the three hours' boiling with hydrochloric acid of 3%, was now boiled three hours longer and neutralized and decolorized as before. It gave quasi $(a)D = 40°.54$ and "dextrose" amounting to 9.97% of the dry wood, showing that in the absence of wood some of the products of the first hydrolysis were readily destroyed by the hot dilute acid.

On evaporating this solution to dryness and treating the residue with cold, strong alcohol, the matter less soluble in alcohol gave quasi $(a)D = 42°.27$, and the readily soluble portion gave quasi $(a)D = 22°.17$.

The residual cellulose from the wood which had been boiled with 3% hydrochloric acid was washed and allowed to dry in the air; it was then left to soak for 24 hours in 100 c.c. of hydrochloric acid of 35%, and the mixture was poured into enough boiling water to reduce the acid to the strength of 3%. The mixture was boiled during three hours over a free flame, as before. Evidently the strong hydrochloric acid had but little action upon the wood.

One half of the filtrate was neutralized with sodium hydroxide, evaporated and decolorized. It gave quasi $(a)D = 85°.7$ and dextrose equal to 0.98% of the dry residue, or to 0.78% of the dry wood. It is to be remarked, however, that this observation is of little or no value, because the solution was extremely dilute. It contained absolutely too little sugar to admit of a satisfactory examination. Nevertheless, it was evaporated to dryness and treated with cold, strong alcohol. The portion soluble in alcohol gave quasi $(a)D = 53°.34$.

The second half of the filtrate, obtained after soaking in strong hydrochloric acid and subsequently boiling in this acid diluted to 3%, was boiled three hours longer, but so little sugar was con-

tained in the liquid that no tests could be made. It is noticeable that hydrochloric acid of 35% has no such power to break up the cellulose in wood as is exhibited constantly by strong sulphuric acid.

The residual wood left after the treatment with strong hydrochloric acid, and subsequent boiling with the 3% acid, was mixed thoroughly with 10 c.c. of strong sulphuric acid (90% H_2SO_4) and left at rest for 24 hours. The black, pasty mass was poured into enough boiling water to reduce the strength of the acid to 3.5%, and the mixture was boiled for three hours. The filtered solution was neutralized with calcium carbonate and tested. It did not need to be decolorized. It gave quasi(a) $D = 92°.9$ and 23.72% of sugar calculated as dextrose on the dry residue, — or 18.83% calculated on the dry wood. When this solution was evaporated and treated with cold, strong alcohol, the matter left undissolved gave quasi(a) $D = 71°.60$, and the portion soluble in alcohol gave quasi(a) $D = 54°.93$. On again evaporating the aqueous solution of the matter not dissolved by alcohol and treating the new residue with cold, strong alcohol, — in order to dissolve out as much dextrose as might be possible, — there was obtained a new fraction insoluble in alcohol which, on being dissolved in water, gave quasi(a) $D = 85°.88$. There was not enough matter dissolved by the alcohol to admit of any critical examination, but the solution was set aside to evaporate, and after six months it was noticed that the solid residue had segregated in the form of isolated tufts or balls (presumably of dextrose) rising from the centres of thin, starlike radiations of crystals.

The second half of the filtrate from the hydrolysis with sulphuric acid of 3% (after the action of strong sulphuric acid) was boiled three hours longer and examined as before. It did not need to be decolorized. That it had suffered considerable alteration was shown by the fact that it now gave quasi(a) $D = 64°.49$, and 28.27% of dextrose calculated on the dry residue, or 22.45% calculated on the dry wood. After evaporating to dryness and treating with cold, strong alcohol, the matter not readily dissolved in this liquid gave quasi(a) $D = 58°.66$, while the portion soluble in alcohol gave quasi(a) $D = 49°.85$, both calculated as dextrose.

It should be said that most of these experiments with birch

wood were made before those upon maple wood, as reported
above.   It is evident enough that beside xylose and dextrose
some other substance of higher rotatory power than dextrose is
produced when birch wood is boiled with acids under the condi-
tions here described.

D. *Experiments on the Acid Hydrolysis of Cotton.* — In a pre-
liminary trial a quantity of worn out cotton cloth was boiled in
several successive fresh portions of sulphuric acid of 2.8% H_2SO_4,
and the residual cotton left after this treatment was soaked in
sulphuric acid of 86.3% H_2SO_4 for 24 hours.   Subsequently,
water enough was added to reduce the acid to the strength of
2.8%, and the mixture was heated during 5.5 hours on a boiling
water bath.   On neutralizing with calcium carbonate, evaporating
to the consistence of a thick syrup, and mixing this syrup with
strong alcohol a considerable quantity of sticky, gummy matter
was left undissolved.

In another trial 50 grms. of the cotton cloth were treated
directly with 100 c.c. of sulphuric acid of 90% H_2SO_4, and the
mixture was left to stand during 24 hours, with occasional stir-
ring.   It was then poured into enough boiling water to reduce
the acid to the strength of 6%, and the boiling was maintained
over a free flame for three hours.   The filtered liquid was neutral-
ized with calcium carbonate, evaporated, decolorized with bone-
black, and tested with Fehling's liquor and in the polariscope.   A
rotation of quasi(a) $D = 75°.88$ was noted.   The solution was
evaporated to dryness and the residue was treated with cold,
strong alcohol, in which the larger part of it dissolved, the matter
insoluble in alcohol being manifestly less in this case than in the
preceding instance.   On testing this insoluble matter, after it had
been taken up with water and decolorized with bone-black, a rota-
tion of quasi(a) $D = 81°.58$ was noted and "sugar" enough to
amount to 0.5% of the dry cloth.   The matter soluble in alco-
hol, after having been decolorized with bone-black, gave quasi
(a) $D = 66°.62$ and "dextrose" to the amount of 15.83% of
the dry cloth.

On again evaporating to dryness the solution of the matter
soluble in alcohol and treating this new residue with cold, strong
alcohol, a portion of it was left undissolved, though the undis-

solved matter was small in proportion to that which went into solution. This matter undissolved by alcohol was taken up with water, decolorized with bone-black, and tested with Fehling's liquor and in the polariscope. Taking the sugar found as "dextrose" the rotatory power was quasi$(a) D = 63°.66$, while the matter that dissolved in the alcohol gave quasi$(a) D = 63°.69$ when similarly tested.

Subsequent trials, made after the study of birch and maple woods as above described, gave the results which here follow: Sixty grams of the cotton cloth were left to soak during 24 hours with 70 c.c. of sulphuric acid of 90% H_2SO_4, the mixture was poured into enough boiling water to reduce the acid to the strength of 3.5%, and the boiling was continued during three hours over a free flame. The filtrate was neutralized with barium hydroxide and evaporated to a syrup which was treated with successive portions of strong alcohol, as long as the alcohol became colored. The matter insoluble in alcohol gave quasi $(a) D = 71°.76$.

Attempts to obtain crystals from the matter insoluble in alcohol, by operating in the manner described on page 448, failed. though an abundance of inorganic matter was encountered. After expelling alcohol, by warming upon a water bath the matter insoluble in alcohol, a small quantity of water was added to a portion of it, the mixture was heated to a temperature somewhat higher than $50°$, and set aside in an exsiccator over sulphuric acid. The mass hardened somewhat, although no crystals appeared. Another portion was tested for mucic acid by treating it with nitric acid after it had been dried for a short time at about $100°$ and left over night in an exsiccator, but the precipitate formed by the action of nitric acid was found to consist wholly of inorganic matter. When ignited on platinum foil it did not blacken, but remained white and unchanged.

In the hope of removing this inorganic contamination, a part of the matter insoluble in alcohol was dissolved in water, a current of carbonic acid was passed through the solution during several hours, and the whole was boiled thoroughly. No precipitate of barium carbonate formed, not even when these processes were repeated a second time. The solution was then evaporated and the residue was heated to $100°$, after which it was taken up

with water and treated with dilute sulphuric acid added in slight excess. The precipitate of barium sulphate that formed was removed by filtration, and lead carbonate was added to the filtrate to get rid of the sulphuric acid. After filtration the solution had an acid reaction when tested with litmus paper, but it gave no precipitate when tested with barium nitrate. Sulphuretted hydrogen gas was passed to remove lead, the filtrate from the lead sulphide was evaporated to dryness and the residue was treated with successive portions of strong alcohol of 93%. The matter insoluble in alcohol gave a slight acid reaction on being dissolved in water, and a rotation of quasi $(a) D = 111°$. The solution was again evaporated to dryness and tested for crystals as before (see page 448), but none appeared. The dark-brown syrupy mass, on being treated with successive small portions of pure methyl alcohol, dissolved completely. This methyl alcohol solution set aside in a cold room, in mid-winter, dried down to a syrup of the same appearance as before; it was now washed with ethyl alcohol of 93% until all traces of acidity had been removed from it. On being dissolved in water it tasted somewhat bitter, with a suggestion of sweetness. A portion of it was tested for mucic acid, with nitric acid, and none was found, — a result which consists with that of a similar trial made by Braconnot.

Yet another portion of the matter insoluble in alcohol (of page 455) was dissolved in water and filtered, dilute sulphuric acid was added, to precipitate barium, if possible, and subsequently lead carbonate to remove sulphuric acid. Sulphuretted hydrogen was passed to remove lead, and, since the solution gave an acid reaction after the removal of the lead sulphide, a new quantity of lead carbonate was added, and afterwards sulphuretted hydrogen. It appeared, however, that the acidity could not be annulled by this method of procedure. It was only by evaporating the filtrate from the lead sulphide to the consistence of a syrup, and washing this syrup with strong alcohol that the last traces of free acid were removed. The syrup thus washed, when freed from alcohol and dissolved in water, had a peculiar, disagreeable odor, and a sweetish though somewhat bitter taste.

After complete removal of the acidity the syrup was dried carefully at a temperature of 70° to 80° C., and finally weighed after it had been heated for a short time to 100°. The rotatory power

of this matter, based on the actual weight of the solution examined, was found to be $(a) D = 63°.22$; and on testing the solution with Fehling's liquor it appeared that the reducing power was 0.2163, that of pure dextrose being regarded as equal to 1, — that is to say, the reducing power was about one fifth that of pure dextrose anhydride. It is noteworthy that on calculating the rotatory power from the quantity of "dextrose" — that is, reducing matter — shown by Fehling's liquor to be present in a measured volume of the solution, the extraordinary figures quasi$(a) D = 330°.9$ were obtained.

For the sake of testing more explicitly, than had been done in any of the foregoing experiments, some current statements as to the large percentage of dextrose that may be obtained on hydrolyzing cotton, after treatment with strong sulphuric acid, the following trials were made : —

I. After Flechsig,[*] 250 grm. of air-dried, well-worn cotton cloth, that had been cut into small fragments, were put, little by little, into a cooled mixture of 1250 grm. commercial sulphuric acid of 92.5% H_2SO_4 and 420 grm. of water. After the lapse of one hour the mixture of cotton and acid was diluted with two thirds its volume of water, and the whole was left to stand for one day. According to Flechsig, the mixture should now have been filtered; but it was so thick and adhesive that filtration was simply impossible. Instead, therefore, of filtering and making up the volume of the filtrate to 2.5 litres, enough water (some 700 c.c.) was added to the mixture of acid and cotton to bring its volume up to 2.5 litres, and it was found to be practicable to filter this mixture slowly with the aid of a suction pump. From the filtrate thus obtained, 50 c.c. were taken and mixed with water enough to bring the volume up to 900 c.c.; and the solution thus diluted was boiled over a free flame for six hours, in a flask with reflux condenser, and then neutralized with a hot solution of barium hydroxide. Finally, a small quantity of barium carbonate was added to complete the neutralization. After filtration the neutralized liquor was evaporated to the volume of 97 c.c. It gave quasi$(a) D = 54°.64$, and Fehling's liquor indicated dextrose enough to amount to 30.26% of the cotton taken (regarded as dried at 100°).

[*] Zeitschrift für physiologische Chemie. **7.** 528.

Returning now to the soft, pasty mass which remained undissolved when the mixture of strong acid and cotton was diluted with water, efforts were made to wash and collect this material in order that its weight might be subtracted from that of the cotton taken. To this end it was stirred up repeatedly with fresh portions of water and refiltered many times. Although it still retained an acid taste, the grayish mass was dried somewhat on a water-bath where it turned brown and eventually black. As soon as the pasty particles had begun to ball together on stirring a new attempt was made to wash the material, but it became pasty again on the addition of water. Finally, the matter was dried at 100° in a current of air and weighed. It amounted to 27.82% of the original cotton dried at 100°. From the nature of the case, the subtraction of this highly impure material from the weight of the cotton can be regarded as affording only a rough approximation to the quantity of cotton that escaped solution; but it is noteworthy that, after the subtraction of this insoluble matter, the percentage of dextrose yielded by the cotton cloth, minus the insoluble matter, amounted to no more than 41.92% of the dry cotton.

A quantity of the clear neutralized filtrate, resulting from the hydrolysis of the dissolved cotton, was evaporated to dryness on a water-bath, and the residue was treated with several successive portions of cold, strong alcohol. Apparently, less than half of the residue dissolved; and, from evidence presented on previous pages, it is to be presumed that some part of this substance insoluble in alcohol must have been inorganic matter. After expelling the alcohol and dissolving in water, the matter insoluble in alcohol gave quasi (a) $D = 55.°25$, and Fehling's liquor indicated enough dextrose to amount to 17.38% of the original cotton (dried at 100°), or to 24.07% of the cotton, after subtraction of that portion of the cotton which was left undissolved by the sulphuric acid.

Although the percentage of dextrose obtained in this particular instance is very much less than the quantity reported by Flechsig in the experiment made by him, of which the trial here reported is a repetition, it is noteworthy that the rotation observed (quasi (a) $D = 54°.64$) is decidedly nearer that of pure dextrose than had ordinarily been detected in any of the very large

number of tests made in this laboratory on products of the hydrolysis of cotton and woods of various kinds. Moreover, the rotation here exhibited by the matter insoluble in alcohol (quasi(a) $D = 55°.25$) is much nearer that of pure dextrose than had been observed in this laboratory in any previous instance where analogous materials were tested. But in the previous trials, the condition under which the hydrolysis of the cotton had been carried out were less closely akin to those commended by Flechsig than in the present instance, where his method of procedure was copied as closely as possible.

It would appear, therefore, that Flechsig's method of hydrolyzing cotton, by means of acid of special strength, has real merit, although the conversion of cellulose to dextrose may perhaps never be so nearly complete as he was led to believe.

II. The following trial was meant at first to be in precise imitation of the work of Winterstein,* though the method finally adopted differs from his in that lead carbonate was here used to neutralize the acid product of the hydrolysis : —

0.9302 grm. of worn cotton cloth, dried at 100°, were rubbed up with 5 grm. of sulphuric acid of 92.5% H_2SO_4, and allowed to stand during 12 hours. After diluting with water, the brown solution was thrown upon a tared filter which retained nothing. The solution was made up to 200 c.c. and boiled during two hours. A sediment formed which, on being collected, washed, dried and weighed, was found to amount to 0.043 grm. The clear filtrate was neutralized with lead carbonate. After filtration sulphuretted hydrogen gas was passed to remove any dissolved lead, and the solution was filtered and boiled to remove the excess of sulphuretted hydrogen. On being tested with Fehling's liquor sugar enough was found to amount to 52.34% of the dry cotton taken, or to 54.87% of that cotton, if we subtract from the weight thereof the weight of the small quantity of insoluble matter that was deposited during the hydrolysis. These last figures correspond to 49.4% of the theoretically possible dextrose (111.1) which might be obtained from 100 parts of cellulose if it were practicable to change the whole of it to dextrose. The rotatory power of the solution was found to be quasi(a) $D = 125°.2$.

The larger part of the solution was evaporated to the consist-

* Die landwirthschaftlichen Versuchs-Stationen. 1892, **14.** 383.

ence of syrup which was treated with cold, strong alcohol in which some of it dissolved; hot alcohol dissolved little more of it than cold alcohol did. The dextrin-like residue insoluble in strong alcohol was dried at 70° C. until it ceased to lose weight. There was 0.299 grm. of it, which was dissolved in 50 c.c. water. The reducing power of this solution was tested carefully with Fehling's liquor in comparison with that of a solution of pure dextrose. It appeared that while the reducing power of dextrose anhydride was 1, that of the matter insoluble in alcohol was 0.4122. In a previous trial, where the dextrin-like material had been prepared by a more circumstantial process, a reducing power of 0.2163 was observed, as has been said.

It must be observed, however, that neither of these tests of the reducing power of the "matter insoluble in alcohol" was wholly satisfactory. I am inclined to believe, indeed, that the use of lead carbonate for neutralizing the acid products of hydrolysis is inadmissible. The extremely high and manifestly abnormal rotatory power of several of the "dextrins" observed after the use of the lead carbonate make it evident that the results obtained after neutralizing with this agent are not directly comparable with those got by means of barium and calcium compounds. Several chemists have called attention to the fact that by the action of one or another lead compound on sugar the rotatory power and other properties of the sugar may be changed, and it would seem that this remark must be true also of the case where lead carbonate is used for purposes of neutralization. It was very noticeable withal in my experiments that the syrups obtained by evaporation after the use of the lead carbonate were of decidedly darker color than those got by neutralization with calcium carbonate or barium carbonate or hydroxide; they were, in fact, very dark, and of unpleasant, molasses-like appearance.

A satisfactory method of separating quantitatively the dextrose and "dextrins" obtained on hydrolyzing cellulose from the acid and other matters with which they are admixed is still to be desired.

E. *Experiments in which pure Dextrose was treated with strong Sulphuric Acid.* — In contrast with the foregoing observations on cotton, a few experiments were made by treating pure dextrose

with strong sulphuric acid, and noting the reducing and quasi-rotatory power of the products. Thus, 10 grm. of dextrose anhydride were mixed with 14 c.c. of sulphuric acid of 90% H_2SO_4, and the mixture was allowed to stand for 24 hours. No immediate coloration occurred, but gradually the mixture turned brown, and at the end of 24 hours it had become black. The mixture was poured into enough boiling water to reduce the acid to a strength of 3.5% H_2SO_4, and the boiling was continued for three hours. The resulting solution was almost colorless; it exhibited only a slight brown or yellowish tint which did not increase in the course of the subsequent processes of neutralization and evaporation. There was no need of decolorizing the solutions before testing their rotatory power.

One part of the product of the hydrolysis was neutralized with calcium carbonate and evaporated to a thin syrup, which gave quasi $(a) D = 78°.61$, and reduced enough Fehling's liquor to indicate the presence of 69.76% of dextrose, calculated, of course, on the quantity of dry dextrose that was treated with sulphuric acid. A portion of this syrup was evaporated to a thick syrup, which was treated with successive portions of cold, strong alcohol until nothing more was dissolved. There was left a slimy, sticky mass similar in appearance to those obtained by similar treatment from wood and from cotton. It gave quasi $(a) D = 73°.33$.

Another part of the acid liquor which resulted from the original hydrolysis was neutralized with lead carbonate, and the filtrate therefrom was treated with sulphuretted hydrogen; and these processes were repeated a second time for the sake of certainty. After boiling off the excess of sulphuretted hydrogen, the clear solution gave quasi $(a) D = 66°.45$, and Fehling's liquor showed 83.39% of "dextrose." The solution evaporated to a syrup, and treated with strong alcohol, in which much of it dissolved, left an insoluble residue which gave quasi $(a) D = 88°$.

Having in view the well-known difficult solubility of anhydrous dextrose in strong alcohol, one or two experiments were made for the sake of contrasting dextrose precipitated by alcohol with the "matter insoluble in alcohol" mentioned on foregoing pages. To this end a quantity of pure dextrose anhydride (from Merck

& Co.) was dissolved in water, and the solution was evaporated (without boiling) to a syrup which was treated with cold, strong alcohol. Only a part of the syrup dissolved in the alcohol, while there was left undissolved a sticky, stringy mass similar in appearance to the matter insoluble in alcohol so constantly obtained in the experiments on wood and cotton. The matter soluble in alcohol gave quasi $(a) D = 58°.1$. The matter insoluble in alcohol was dried at $100°$ and weighed. Its rotatory power (true) was found to be $(a) D = 53°.03$, calculated on the weight of the solution examined. When tested with Fehling's liquor, 84.56% of the original dextrose was indicated and a rotation of quasi $(a) D = 62°.7$.

In order to be sure that the dextrose operated upon was really in the state, not of the anhydride, but of a hydrate, — such as would naturally be present in the liquors obtained by hydrolyzing cotton or wood, — three grm. of dextrose anhydride, dissolved in water, were boiled for some time, for the purpose of changing the anhydride to the hydrate, and the solution was evaporated to a syrup upon which a quantity of strong alcohol was poured. In this case the strong alcohol, either cold or hot, readily dissolved the larger part of the syrup. To all appearance more than three fourths of the syrup went into solution when treated with successive portions of the alcohol, while less than one quarter of the syrup remained undissolved. It is perhaps not impossible, even in this case, that the strong alcohol may have dehydrated some of the dextrose which had been held in solution as a hydrate, and have thrown it down as an anhydride. If this conception be valid, it follows that some part of the reducing power exhibited by the "matter insoluble in alcohol," obtained from wood and cotton, may really be due to the presence of dextrose in that matter. But, on the other hand, it may equally well be true that the aqueous solution in this experiment was not boiled long enough, before it was evaporated, to change all the original anhydride to a hydrate. It is not impossible perhaps that if the aqueous solution of the dextrose anhydride had been boiled longer than it was, the conversion might have been so complete that alcohol would have dissolved everything. Lack of time has prevented me from studying this point.

Some conclusions to be drawn from the foregoing experiments may be stated as follows : —

I. When strong sulphuric acid is made to act upon cellulose, and the product is subsequently boiled in dilute acid, it is not true that the whole of the cellulose may readily be changed to dextrose. The statements made in relation to this subject in most chemical text-books are faulty in several respects.

II. It is a well-known fact that when strong sulphuric acid is made to act upon carbohydrates, — that is, upon starch, sugars, dextrins, or cellulose, — compounds of the carbohydrate and the acid are formed. At one time or another these compounds have been called by several different names, — for example, vegeto-sulphuric acid, sulpholignic acid, sulphoglucic acid, dextrose-sulphuric acid, cellulose-sulphuric acid, etc.,* — and it has been held not uncommonly that they may be decomposed pretty thoroughly by the long-continued boiling in diluted acid which occurs in the actual process of hydrolysis. In point of fact, it is by no means an easy matter to decompose these compounds completely by way of hydrolysis. As a general rule, no inconsiderable part of the organic matter with which the strong acid united at first is not changed to dextrose when boiled subsequently in the diluted acid. Some part of this undecomposed matter remains admixed with the dextrose-syrup, and, in experiments such as have been described above, it must necessarily tend finally to contaminate the solid dextrose obtained from the syrup.

III. In spite of the fact that solutions of salts of the above-mentioned compounds of a carbohydrate and strong sulphuric acid are highly unstable, it appears to be by no means easy to decompose such solutions *completely*. Even after long-continued boiling of dilute solutions of the calcium or barium salts of these copulated acids, some portions of the salts are apt to escape decomposition and to contaminate the dextrose syrups. When strong alcohol is added to such syrups any remnants of the sulpho-salt which may be present will remain undissolved by the

* Compare Braconnot, Annales de Chimie et de Physique. 1819, **12.** 173. Peligot, *ibid.* 1838, **67.** 113. Blondeau, Journal für praktische Chemie. 1844, **32.** 429. Fehling, Annalen der Chemie und Pharmacie. 1845, **53.** 134, and **55.** 13. Hoenig und Schubert, Monatshefte für Chemie. 1885, **6.** 708.

alcohol, so that a certain quantity of calcium or barium, as the case may be, will be found admixed with the organic matter.

To this cause I attribute the presence of notable quantities of inorganic matter in the syrups obtained by evaporating the neutralized liquors from the hydrolysis of woods and of cotton.   In the experiments described on pages 448–450, it is evident that the processes employed for obtaining crystals and in testing for mucic acid, and those where the acid products of a first hydrolysis were boiled a second time after the removal of the wood, did finally decompose the calcium and barium salts that were contained in the " matter insoluble in alcohol," and so liberated the sulphuric acid from its organic combination in such wise that it could now combine directly with calcium or with barium to form visible crystals or precipitates, as the case might be.

I am familiar with the fact that more gypsum can be held dissolved in solutions of sugar than in mere water.   Sostmann * studied this matter in 1866, and I had myself noticed the fact several years earlier.†   But it has seemed to me in the present experiments that the appearance of the crystals of gypsum, or what not, was a consequence of the decomposition of sulphocompounds by which the gypsum, or rather its components, had previously been masked.

IV. The statement of Béchamp,‡ that on crystallizing his glucose from "lignin" (presumably cotton), he got "two kinds of crystals, one hard as cane sugar, the other ' houppes,' such as those of starch sugar," is readily explained on the assumption that he had in hand crystals of inorganic matter which had resulted from the decomposition of the last portions of the calcium salt of the cellulose-sulphuric acid.   In my own experiments I have, like Béchamp, obtained two kinds of crystals on evaporating my glucose syrups; but, as has been said, the hard, well-defined prisms were not crystals of sugar, — they consisted solely of inorganic matter.

V. Perhaps it was with reference to the foregoing statement

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* Zeitschrift des Vereins für die Rübenzuckerindustrie des deutschen Reiches. **16**. 517.

† As stated in my "First Outlines of a Dictionary of Solubilities of Chemical Substances," Cambridge, 1864, page 608, column 1.

‡ Annales de Chimie et de Physique. (2) **48**. 502.

of Béchamp that Berthelot* was led to remark that "the 'glucose de ligneux,' still little known, appears to be distinct from all other glucoses," though it may be that he recognized more clearly than some of his successors have done that, until it has actually been crystallized, the dextrose obtainable from wood or cotton is a distinctly impure product.

VI. It has been taught by several chemists in recent years that (barring xylose, which may be obtained in small quantity from wood cellulose) no other sugar than dextrose is obtainable on hydrolizing cellulose with acids, and the experiments here recorded consist with this opinion. But, in so far as relates to the *quantity* of dextrose that can be obtained from a given weight of cellulose, I find myself unable to agree with several standard authorities.† On the contrary, I would urge, in view of the lack of purity of the dextrose syrups obtained on hydrolyzing cellulose, that it is difficult to escape the conviction that most of the current statements as to the very large proportion of dextrose that may be obtained from a given weight of cellulose must have been somewhat exaggerated. For the most part, those observers who have obtained large yields of dextrose from cellulose appear to have based their statements solely on the quantity of cupric oxide reduced by the product of their hydrolysis, — that is, their statements refer to the quantity of reducing matter shown by Fehling's liquor when the product of the hydrolysis came to be tested. It is seldom that any experimenter has based his declared results on a definite quantity of dextrose actually separated from the liquor and weighed. But as the foregoing experiments show there are contained usually in the saccharine solutions, which result from the hydrolysis of cellulose, other matters beside dextrose that are capable of reducing no inconsiderable quantities of Fehling's liquor.

VII. In the light of existing knowledge it is to be presumed that the "matter insoluble in alcohol," so constantly referred to on the foregoing pages, consists for the most part of a more or less impure "dextrin" which has resulted from the decomposition of the copulated acid that was formed in the beginning by the

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* Annales de Chimie et de Physique. 1859 (3), **55**. 293.

† Compare Lippmann, Chemie der Zuckerarten, Braunschweig. 1895, page 104.

action of the strong sulphuric acid on the cellulose. The general appearance of the substance now in question, and some of its properties, seem to show a strong family resemblance to the dextrins proper, though the fact that it exhibits a higher reducing power than the true dextrins, fosters a lingering suspicion that it may possibly contain an amorphous sugar analogous with or even akin, in one sense, to isomaltose (gallisen). It is not impossible, indeed, that the mere act of adding strong alcohol to the syrup obtained on evaporating the neutralized product of an hydrolysis may serve to dehydrate a small portion of the dextrose in that solution, — that is to say, some dextrose-anhydride may perhaps be formed, and as this substance is but little soluble in absolute alcohol, enough of it might remain in the precipitate to account for the reducing action which solutions of the precipitate exhibit. However this may be, it is manifest that the major part of the precipitate insoluble in alcohol is a body of the same order as those which Hoenig and Schubert * have described as dextrins in their very elaborate research; and it especially resembles the " dextrin de ligneux " that was obtained long ago by Béchamp,† by means of a method almost precisely similar to my own. Béchamp treated cotton or wood with strong sulphuric acid to which he subsequently added much water, and after thoroughly boiling the diluted liquor he neutralized it with calcium carbonate and evaporated the filtrate to a syrup. By means of strong alcohol he separated the " dextrin de ligneux " from the syrup, while dextrose went into solution in the alcohol and was crystallized therefrom. The wood-dextrin thus obtained must have been contaminated like my own with small quantities of a calcium salt. It gave him a specific rotation of $(a)j = 88°.9$,‡ while that of dextrin made from starch was $(a)j = 176°$, and that of soluble starch was $(a)j = 211°$.

By an unfortunate typographical error in Béchamp's article, as published in the *Comptes Rendus*, **51.** 256, — that is, by the mere

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* Monatshefte für Chemie. 1885, **6.** 708, and 1886, **7.** 474.

† Annales de Chimie et de Physique. (2) **48.** 463, and especially 1856 (3), **48.** 352. See, also, in Comptes Rendus. 1856, **42.** 1213, and 1860, **51.** 256.

‡ If it be admitted, with Brown and Heron (Journal of the Chemical Society of London. 1879, **35.** 605), that $(a)j : (a)D :: 24 : 21.54$, then $(a)j = 88°.9 = (a)D = 79°.79$.

misplacing by the printer of a character representing a bent arrow in such wise that the arrow was made to point to the left instead of to the right, — it was there made to appear that the rotation of the wood-dextrin is to the left, though a careful reading of the context shows clearly enough that Béchamp meant to assert that the rotation of this substance is really towards the right hand. It is to be noted, moreover, that Béchamp was one of the last men in the world to speak of a left-handed *dextrin;* for he worked at a time when the word " dextrin " was new, and he had always in mind the derivation and the real meaning of the word. In his memoirs he refers repeatedly to the fact that the substance named " dextrin " by Biot was really not the substance known as " dextrin " in commerce, but an impure soluble starch (now often called amylo-dextrin). The misprint was copied unwittingly into several standard works,* where it has remained an effective stumbling-block to perturb the unwary.

VIII. The difficulty of studying the products of the hydrolysis of cellulose is manifestly increased by the fact that not only do " dextrins " result from the splitting up of the copulated compounds formed by the union of strong sulphuric acid with carbohydrates, but that phenomena of reversion of dextrose to dextrin may occur in the process of hydrolyzing with diluted acids. What connection there may be between the dextrins thus formed by reversion of dextrose and those obtained by the breaking down of cellulose-sulphuric acid, appears to be still an open question. It has been reported merely that the reducing and rotatory powers of the former are lower than those of the latter.

I am greatly indebted to my assistant, Mr. Winfred W. Braman, for his careful attention to the performance of many tedious and discouraging details of manipulation, which have had to be worked out in the course of this investigation.

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* See, for example, the Cavendish Society's edition of L. Gmelin's Handbook, **15.** 188; and Watt's Dictionary of Chemistry. 1866, **2.** 313, 314. So, too, in the 1862 (German) edition of Gmelin's Handbuch. **7.** 633, where the error was evidently copied from the English edition.

It is noteworthy that the editor of the Journal für praktische Chemie on translating, for publication in his journal (1861, **82.** 121), Béchamp's article at the time of its appearance, corrected the misprint, though without comment. Hence the error does not appear in those German treatises which have taken their information from the Journal für praktische Chemie.

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